ILLUMINATING ENGINEERING

MAY, 1949

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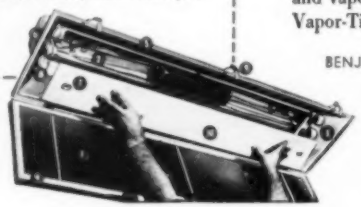

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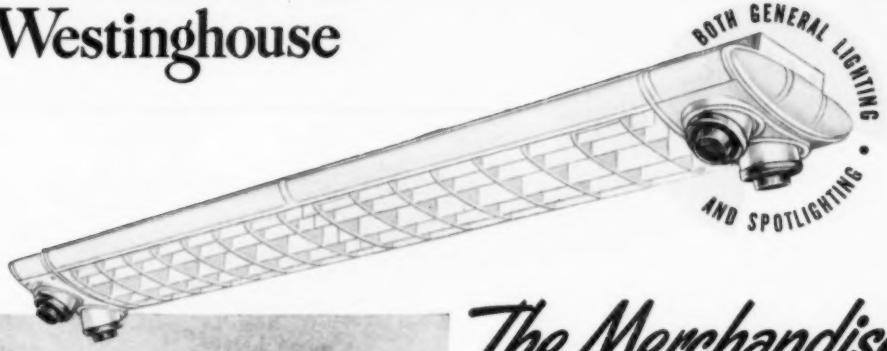

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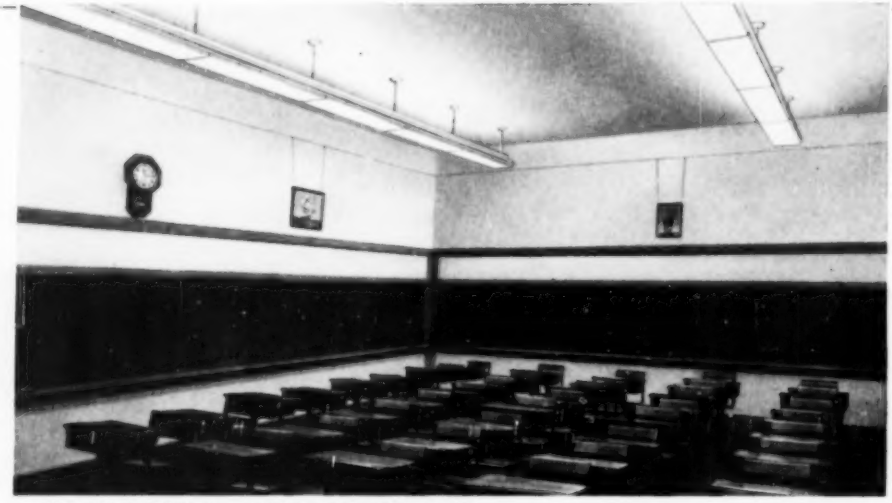

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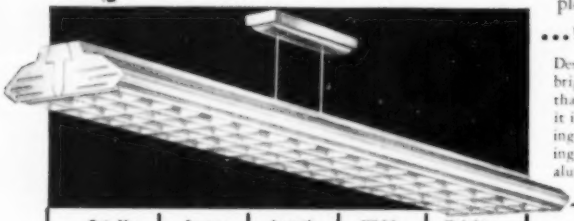

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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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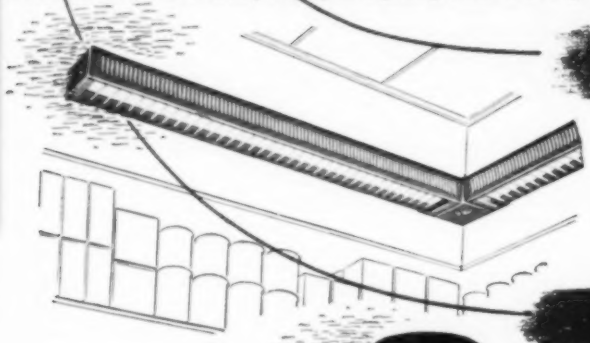

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Studies of Lighting and Seeing for the Student at Home

By MARY E. WEBBER

This paper analyzes the lighting results obtained from twenty representative luminaires that are popularly advocated and used for home study. Photographs show the luminaires tested in identical settings, and give luminaire dimensions, spacing from test plane, and the brightness values of luminaire, test plane, and visual field. The comparative test data and comments presented reveal inadequacies too often overlooked, as well as the characteristics which contribute to comfortable lighting. By discussion of desk placement, size, and finish, and the students' eye position, emphasis is given to their importance in lighting for ultimate satisfaction and eyesight conservation. The tests applied in every case suggest a pattern for complete and standardized evaluation of a luminaire's ability to supply the most favorable lighting for study in homes and student dwellings.

DURING the greater portion of the school year, homework must be done under artificial lighting. Homework is often required at eighth grade and even earlier; hours of home study increase as educational level progresses. According to statistics, a marked increase in the numbers of nearsighted students is indicated.[1] Study hours involve critical eye work, fixed position, and mental attentiveness. The eye-use, posture, and mental habits formed in this learning period have an influence throughout a lifetime. A simple, planned study center that provides the best possible lighting for the eyes' needs, the most comfortable posture, and the least visual and mental distraction is of utmost importance.

To date, only one directly-measurable element of a study center—quantity of light—has been established in the "Recommended Practice of Home Lighting."[2] Other elements are hence subject to studies such as are set forth in this paper in order to arrive at sound evaluation and more complete recommendation.

Figure 1. Good lighting and those other important factors—student eye position, desk finish and placement, and book angle—are correctly interrelated in this planned study center. The wall tackboard is an important element of the visual environment planned for student comfort.

Over fifteen years ago the Society recognized the need for specific attention to the study problem. As a result of committee investigation, specifications were prepared covering lighting performance qualities, and the first certified study lamp was introduced in 1934.[3] Experience indicated that it was a fine first step in meeting the problem. Perhaps the model was incorrectly interpreted as the only size and shape possible for satisfactory results. Since then the philosophy and standards of good lighting requirements and seeing conditions have progressed with study, experiments, and knowledge. These newer standards now need practical application to the study center.

Home survey[4] and experienced observation reveal glaring inadequacies in even the basic requisite of lighting for study. Many students are able to attain but small fractions of the recommended amount due to the very low wattage prevalent in luminaires used for study. Many students, too, use the kitchen, dining, or card table. In dormitory and student dwelling room there is at least provi-

MISS WEBBER is with the Engineering Div., Lamp Department, General Electric Co., Nela Park, Cleveland, Ohio.

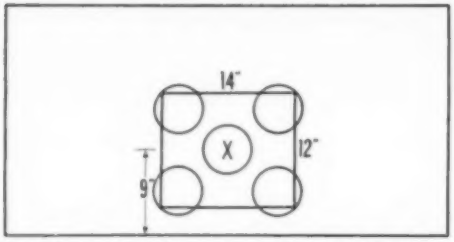


Figure 2. Position of test plane on desks and location of light meter cell on test plane. Scaled for 24" x 46" desk.

sion of study desk and chair, but these form only the start.

Lighting is the dominant element in study and has bearing on posture and attitude[5] as well as on seeing. Any study of lighting must start with the selection of practical related conditions, which for this study include:

(1) Desk placement in the room.
(2) Finish and size of desk.
(3) Student eye position.

Desk Placement

A location with the desk flat against a wall was selected. This placement utilizes the diffuse reflection from the wall for increasing the light on the work area. It sets specific and known boundaries to the normal visual field of the student and can be readily controlled in brightness. In this selected placement, a well-designed luminaire can light the desk and the visual field with little or no dependence on other lighting.

A desk in the corner of a room, taking advantage of the reflecting surface of two walls, provides somewhat higher light levels. Corner placement is particularly suitable if a window is in the left wall for daylighting. A drawn shade must be used to prevent light loss at night. It was not selected for this paper because it is not so often applicable in practice and it favors certain luminaire designs more than others.

Placement in the room center imposes some loss of light plus mental and visual distraction. The really difficult problem is that of brightness control of that large portion of the room now in front of the student, the lighting of which must be considered simultaneously. Desk placement at right angles to a wall is often decoratively desirable and is suitable for desks not used for long study hours. The problem of control of visual field is similar to that of room center placement.

A study desk should never face a window. Daytime activities out of doors are distracting and sky brightness is directly ahead of the student. Correct window shade treatment is required to conceal its night blackness.

The character of wall treatment is obviously of great importance in the selected flat-against-wall desk placement. It should be non-glossy and reflect light generously in the order of 45 to 65%. A bold, high contrast, or "busy" pattern is distracting and often reduces the walls' light reflectance. Conversely, an absolutely plain finish allows no satisfying detail for eye focus. When wall finish is unsuitable, a framed tackboard hung from the cornice over the desk is a practical solution. Celotex is inexpensive, has texture and visual interest, and has a reflection factor of about 65%. Its dimension should be related to the desk size—in general approximately 36" x 42" (Fig. 1). It also offers a means of hanging light-weight wall luminaires in those rooms where "house rules" forbid attaching anything directly to walls.

Desk Finish and Size

A desk top finish of flat, non-glossy paint, 35% R.F., was selected for the tests. Blonde desks, cur-

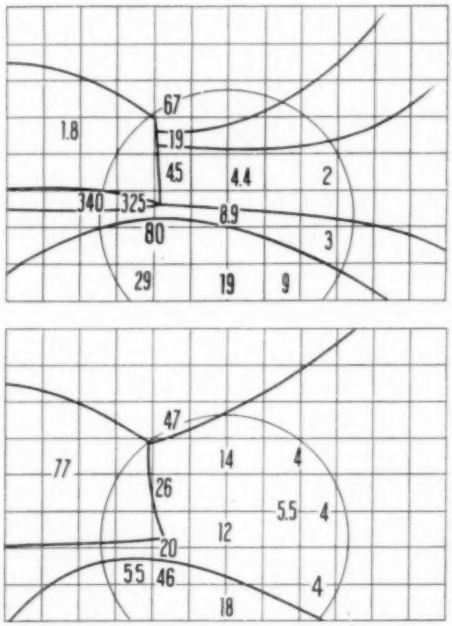


Figure 3. Sketches of the relaxing zone view of the wall and projected outline of the luminaire. The grid lines on the wall are 6" apart and the circle represents the relaxing zone (30° in all directions from the line of sight). From the lamp shade at the left lines curving away outline the characteristic pattern of shadow and brightness as indicated by the footlambert values. Top sketch represents Test No. 10, for example; lower sketch, Test No. 11.

rently popular, fulfill these requirements. With desk tops of dark finish (less than 25%), it is impossible to avoid distracting brightness difference between the lighted task and its background. Glossy finishes reflect bright portions of the luminaire annoyingly. Old desks may be painted or covered with jaspe linoleum,* already widely used on office desks. For mahogany, walnut or glossy desk tops, large pastel blotters should cover the "working" area of the desk top.

The author chose three desk sizes for study: 20" x 38", 24" x 46", and 30" x 50", each 30" high. The small size allows insufficient space for study equipment, and it forces the student to sit closer to the wall than is felt desirable. The largest size is ideal in the two respects mentioned, but the large wall and desk area are less easy to light with conventional units. Great numbers of desks in the medium size are in use. Hence many of the tests were of luminaires suited to and used on this desk size.

In general flat top desks are preferred for extended study use. The drop-shelf types provide very small working area. They usually require floor lamps. Unless light in finish, the upper section, directly ahead of the student, presents an undesirable dark area in distracting contrast to task brightness.

Student Eye Position

An eye position of 44" above the floor—14" above the 30" desk top—was selected. This represents a minimum for obtaining normal distance between eyes and reading material. Home desks and chairs, standard at 30" and 18" heights respectively, are designed for adult proportions. The young or small-statured student (see Table I) is forced to use chair cushions to locate the eyes sufficiently above the desk top to obtain normal distance between eyes and task.

The eyes of adults, seated in erect position on a chair 18" high, are more than 44" above the floor. However, measure of eye positions when persons are studying in a relaxed position indicates that the 44" eye position is representative. There are of course exceptions: Eyes at higher positions than selected will experience no negative reaction to luminaires designed or placed for the selected eye position. Eyes at lower positions do, however, experience such negative reaction, and chair cushions or more erect posture becomes essential.

*Armstrong Cork Co., Lancaster, Pa.

TABLE I

Eye Level When Seated Upright on Eighteen-inch Chair

Grade	VII	VIII	High School	Adult
Age	13	14	15-18	
Eye Level	39"	42½"	44"	48.7"**

*For 80% of school children; from data contained in American Seating Company catalog #266.

**Average of mean positions for 90% of men and women; maximum deviation below and above is 3.1, from data in Scientific Basis of Illuminating Engineering by Parry Moon, McGraw-Hill Book Co., Inc., Table LVII, p. 520.

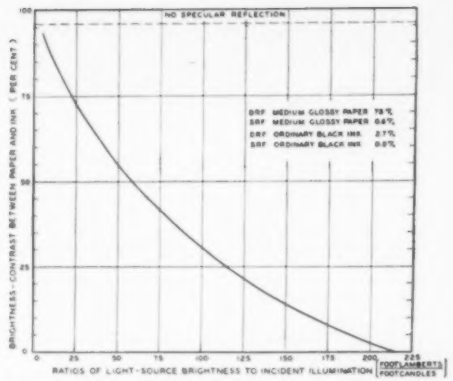


Figure 4. The curve[9] (see References) shows the decrease in brightness contrast per cent in areas of specular reflection when light source brightness (footlamberts) is great compared to incident illumination (footcandles).

Eye position is important not only in relation to visual task but also to luminaire. It is a controlling factor in the height of the lower edge of the luminaire. When the distance between a 30" desk top and the lower edge of the luminaire is more than 15", the eyes at the selected 44" position see into the luminaire. The resulting brightness is annoyingly high and generally distracting.

Selection and Placement of Luminaires

Representative portable lamps of floor, table, and wall types were selected with special reference to their popular use, promotion, or suitability for study desks. Ceiling or built-in luminaires are omitted because of their infrequent use in homes. Many portable types were omitted because their design makes them incapable of providing the recommended average level of 40 footcandles.[1]

One lamp that utilizes an incandescent filament inside-frosted lamp without a diffusing bowl is included to point up the shortcomings of this type (see Test No. 6). The relatively low brightness fluorescent tube requires no additional diffusion.

Placement of the luminaire with respect to the test plane is shown on each photograph. Conventional table types are located at the left side. Placement at the right is correct for left-handed persons. Table lamp types were placed halfway between the front and back edges of the desk and at the distance noted on the photographs between the vertical axis of the lamp bulb and the *desk center*. Keeping the vertical axis of the lamp in line with

the *test-plane center* rather than the desk center would be more advantageous but not as balanced in appearance. Far too many times in practice the lamp is placed as far to the side of the desk as possible. This placement is disadvantageous because it reduces the illumination on the test plane and creates high wall brightnesses.

In the case of luminaires designed for placement directly in front of the student, the designated distance on the photographs is from the horizontal axis of the lamp bulb to the center of the *test plane*.

Test Procedure

Test Room and Test Controls.—The tests were conducted in a room twelve feet square, closely approximating the standard test room,[6] with an 8′ 6″ ceiling, 75% R.F.; walls 48% R.F.; and floor 30% R.F. A 4′ x 6′ board was hung at desk-top level on the wall against which the desks were placed. This board was painted a warm gray, 55% R.F., with just enough stipple to give an interesting textured effect. Black thread divides the wall board into six-inch squares for a quick estimation of the relative areas involved in the wall brightness pattern.

All lamp bulbs used in the tests were seasoned, measured for light output, and operated under controlled voltage conditions.

A test plane 12″ in depth and 14″ wide[6] was positioned on the desk tops as shown in Fig. 2. Provision was made to tilt the test plane 30° toward the user.

The five-inch diffusing test plate, color and cosine corrected,[7] was used for illumination measurement. The Luckiesh-Taylor brightness meter was used for brightness measurement. In the case of luminous shades, average brightness was calculated from footcandle readings taken at 10 feet in a black room.

Illumination Measurements

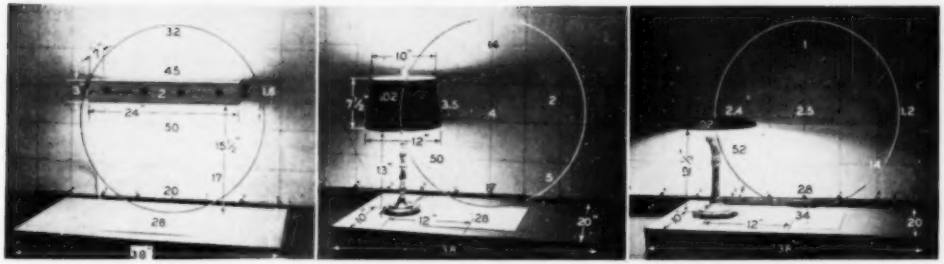
Five illumination readings were taken on the horizontal and tilted test planes with the cell placed as shown in Fig. 2. Because of the thickness of the light-sensitive cell, the luminaire was blocked up to preserve the correct distance between light source and plane of measurement.

In order to obtain the ratio of direct and indirect illumination, two additional series of illumination measurements were made. With the top and outside of the luminaire covered with black cloth and with black cardboard covering the walls, the illumination from the light source and inner reflecting surface of the shade was obtained. This value subtracted from the total illumination, including upward light, transmitted light, and light reflected from the wall and ceiling supplies the "indirect illumination" value. The ratio of 85:15 for example indicates 85 parts of direct illumination and 15 parts of indirect illumination. The data are reported in the photograph captions as the ratio of direct to indirect illumination and serve as one indication of diffusion and comfort of the lighting provided.

Measurements of Brightness of Work Surroundings and Luminaire

The visual field within which brightness ratios have the greatest bearing on comfort has been established[1,8] as having an extent of approximately 30° in all directions from the line of sight. While

Figure 5. Left, experimental handmade model designed as a suggestion for possible restyling and commercial development. A minimum of 22″ between sockets is recommended, with a height of 15″ from desk top to lower edge of shade, 6″ diffusing bowls, translucent shades, and two 100-watt lamps. At right is shown suggested design for two 20-watt (or 15-watt) fluorescent lamps, using plastic top and bottom shielding and adjustable arms. Adjustable for height and for distance from wall, the suggested model could be developed for either hanging on the wall or for desk placement.



Test No. (1) Left. Simple shielded fluorescent lamp (centered 6" out from wall) produces fairly even illumination on test plane and satisfactory wall brightness pattern. Distraction effect of opaque shield is not marked due to its narrowness and light finish. Specular reflection in narrow band across upper section of test plane not too serious due to low brightness source. It may be completely avoided by holding book in desk center at 40° tilt. Deeper desks would require relative increase in lamp position out from wall, maintaining the same relationship of lamp to plane center. Models using longer lamps obviously provide more uniform coverage for desks of greater left-to-right dimension. Decorated white metal shield covers white enamel channel and 20-watt fluorescent lamp; 30-47 ft-c, average 40. Source brightness: 1900 ft-L; ratio direct to indirect illum.: 80:20.

Test No. (2) Center. Shade size and vertical distance from desk top to lower shade edge approaches the minimum for acceptable test plane lighting even for very small desks. Raising the shade 1" and using more flaring shade reduces the ft-c variation on the test plane. Opaque shade creates a distracting dark area on wall (55% R.F.) requiring additional 10 ft-c from other light sources to effect ratios approaching 3 to 1. Unavoidable sheen in small area (11 sq. in.), lower left test plane. Dark green metal shade, white interior, 6" glass waffle pattern bowl; 100-w lamp; 21-60 ft-c, average 40. Source brightness: 2300 ft-L; ratio direct to indirect illum.: 87:13.

Test No. (3) Right. Luminaire design provides effective spread of direct light over test plane on small desk. Moving the luminaire 3" to left away from test plane causes marked change in lighting uniformity. At least 15 ft-c applied to wall are desirable to reduce the trying extremes of light and dark areas on the wall. Potential specular difficulties, serious in reducing print visibility in a small area of test plane, arise from the 8000 ft-L image of lamp in the under side of the reflector. Light gray base; bronze flat reflector, interior aluminum; 100-w lamp inset in metal husk completely shielded from test plane; 36-58 ft-c, average 49. Ratio direct to indirect illum.: 93:7.

reading, this includes the work and its immediate background. While the eyes are raised in an attitude of relaxation and rest, it includes the wall ahead of the student as the principal area. These two defined areas are referred to as the reading zone and the relaxing zone. The reading zone consists of only two surfaces, the reading matter and the desk top. These being of known reflectance, their brightnesses are calculated directly from illumination values.

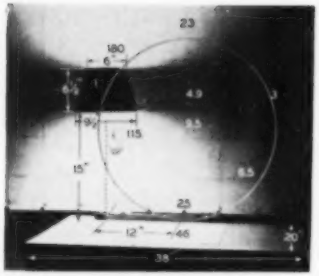
The brightnesses of the relaxing zone were recorded in the laboratory test data in the form of a sketch of the eye's view of the entire scene. The grid of lines on the wall served admirably in delineating the bright and dark areas, as well as in sketching the apparent size and shape of that part of the luminaire falling within the 30° visual field. In Fig. 3 are shown sample sketches indicating how representative brightness readings were spotted around in the field.

From the standpoint of comfort or discomfort during a period of relaxation, it is believed that the eyes are influenced largely by the average brightness effect of masses. Accordingly the brightness of areas is considered as the average of several readings, rather than as a minimum or maximum.

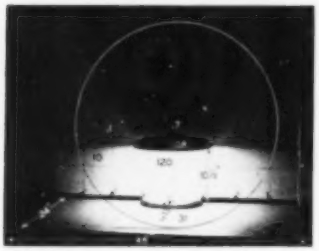
The system based on prescribed eye zones for computing permissible luminaire brightness set forth in the "Lighting Performance Recommendations for Portable and Installed Residence Luminaires"[6] was not utilized. It pertains to a more casual view of the luminaire in a room than obtains in the present problem. Consideration of the viewing positions specified in the "Lighting Performance Recommendations . . ." are of secondary importance to that of first establishing satisfactory seeing conditions for the student only. The direct-viewing brightness limit index must be lower than that permitted for the nearest applicable eye position, Zone B, because the students' eyes are about one foot from the luminaire instead of the three feet noted for Zone B. One computation, made for Test 11, as prescribed in the "Lighting Performance Recommendations . . ." at the three-foot position, gave an index value of 300. For equal areas of shades this represents one third of the brightness allowed.

Measurements Referring to Specular Reflection

Replacing the test plane with a 12" x 14" mirror, the boundaries of the reflected image of the luminaire as seen from the fixed eye position were trans-



Test No. (4) Left. A longer support arm and a deeper shade of larger diameter required to improve ft-c distribution on test plane and to reduce high wall brightness above and below shade. Luminaire cannot be hung nearer desk center without increasing area of already serious specular reflection, due to light-source brightness. Over 15 ft-c needed to adjust uneven wall brightness pattern created by opaque shade. Medium green opaque shade; 150-w R-40 white indirect-lite; 30-115 ft-c, average 66. Source brightness: 4500 ft-L; ratio direct to indirect illum.: 85:15.



Test No. (5) Left. Height of luminaire and light output of lamp prove too low to illuminate test plane with desirable uniformity, even when base is placed this near to test plane. Sharp light cut-off offers very trying extremes in brightness directly in front of user. The addition of 20 ft-c on the upper wall is needed to increase its brightness to about one-third that of test plane. Interior of reflector has low brightness so that area of specular reflection is small but impossible to avoid without serious loss of book illumination. Dark gray finish, semi-circular reflector; interior aluminum, 18-w half-circle fluorescent lamp; 27-70 ft-c, average 45. Source brightness: 2200 ft-L; ratio direct to indirect illum.: 93:7.

ferred to tracing paper. The areas of the reflected bright surfaces were measured as one point of judgment of the seriousness of the specular reflection problem.

At the point of light source reflection, footcandles on a 2" magnesium oxide plate were determined with the brightness meter. Several brightness readings of light source and inner reflecting surfaces were made in the mirror and averaged. These measurements were checked against limiting values of source brightness for given footcandles established in the "Lighting Performance Recommendations . . ."[16] These were exceeded by four of the tested luminaires, Nos. 3, 6, 10, and 11.

Brightness contrast for a specified print and paper was determined from Fig. 4 for each luminaire. Fig. 4[9] is plotted from previous computations and provides a ready source for checking the order of decrease in brightness-contrast as the ratio of source-brightness-to-footcandles increases. On this basis Tests No. 3, 4, 6, 10 and 11 rate low with a brightness contrast below 60% between print and paper.

Polarizing materials were applied in two tests, Nos. 7 and 10, to observe their effects in reduction of specular reflection and total footcandles. These materials function best within certain angles which are not necessarily present in all situations. Outside of these angles the elimination of specular reflection may not be complete. In the specific tests, the specular reflection was much reduced but the average illumination was also reduced 50%. It seems questionable whether the application of present polarizing materials for the conditions involved here is justified.

Interpretation of Test Data

In the present study, the author does not attempt to completely appraise the individual luminaires tested but to emphasize points affecting their lighting performance. Interpretation of the caption comments accompanying the photographs may be aided by a review of those considerations and objectives which guided the author's conclusions.

Illumination Level and Distribution

The recommended illumination for study — an average of 40 footcandles — was attained on the horizontal test plane with the majority of luminaires tested and was exceeded by several. Any commonly used luminaire not included would fail on this point.

Average footcandles for the tilted position are not reported because of marked loss in footcandles or increase in footcandle variation across the page. The tallest table lamp, the floor lamp, and luminaires place directly over the work center exhibited the more favorable illumination in the tilted plane (Tests 9, 16, 7, and 18). If books are pushed back from the specified location, there is improvement of illumination level and smoothness. Some text books are smaller than the test plane and thus would be less subject to the extremes in light level noted. Reading matter can be propped up on a single book

without much sacrifice in illumination, and with some improvement in visual size of the print.

Variation in footcandles on the test plane assumes considerable importance in study lighting, emphasizing that there is no such thing as "even lighting over the work surface." A variation from maximum to minimum of not over 2 to 1 is preferred, and in the author's opinion the low reading should not be less than one-third of the high reading. Typical variations in actual practice far exceed 3 to 1. In too many instances, a substantial portion of the test plane is lighted with less than 30 footcandles. Greater design attention to light-center position, position of lower edge of shade, and shade characteristics would greatly improve uniformity of light spread.[10] Even when these factors are correctly adjusted, the luminaire placement with respect to desk or work center is critical. A distance of 15" from lamp axis to work center represents the practical maximum.

Although illumination of test plane is of first importance, light should not be confined to this area. A student also needs lighted space for extra books and notes for ready and easy reference. Luminaires in Tests 2, 3, 5, 6, and 17 were particularly disappointing in this respect.

The best distribution of illumination over the desk top is found with the use of two luminaires or one of lineal dimension placed over the desk center.

Brightness of Work Surroundings and Luminaire

The recommended ratio of 3 to 1[8] between visual task and surroundings seems to be suitable for study situations. The test and observation period with each luminaire was extensive. Those situations to which reaction was immediately favorable proved upon measurement to be those in which brightness-ratios were substantially in the order of 3 to 1.

Brightness-ratios for the reading zone are within these limits with the 35% desk top reflectance except when the test plane illumination varies more than 3 to 1.

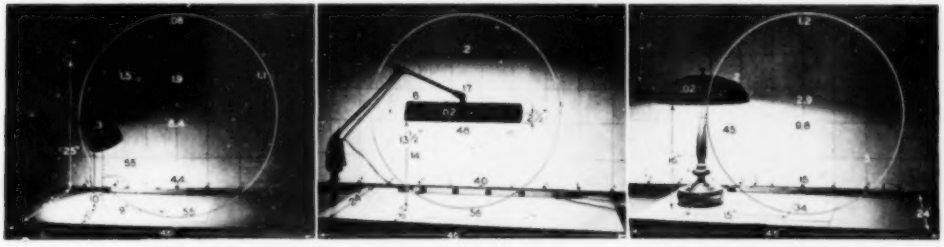
The varied distribution characteristics of the luminaires tested provide great variety of brightness-ratio in the relaxing zone. With increase in indirect illumination there is an improved brightness pattern, and luminaires that use luminous shades exhibit the most favorable result.

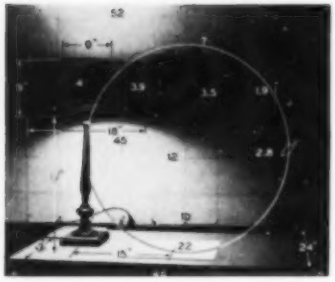
The brightness of luminous shades should also be within a 3 to 1 ratio to both wall and task brightness. For the 40 footcandle illumination level, the author felt that outer shade brightness, relatively uniform, should not exceed 100 footlamberts for comfort. A relatively small area of the luminaire shade is in the relaxing zone when the students' eyes are straight ahead. When luminaire bright-

Test No. (6) Left. Luminaire presents difficulties in satisfactory placement and inherent design obstacles to comfortable study use. As shown, test plane illumination has poor uniformity, impossible to correct without increasing already serious shadow, harshness, and potential specular reflection. Area of specular reflection from the very bright bulb is small, but the resultant "shine" is sufficient to cause disappearance of print of some ordinary magazines. Additional 20 ft-c on wall required to adjust excessive brightness-ratios. Light-gray reflector, inside painted white, completely shielding 60-w lamp from eyes but not from test plane; 36-145 ft-c, average 78. Source brightness: 50,000 ft-L; ratio direct to indirect illum.: 90:10.

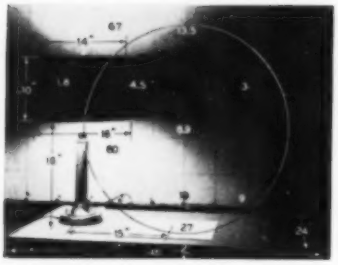
Test No. (7) Center. Adjustable reflector is positioned toward front side of desk and tipped up toward wall 30° to reduce area of possible specular reflection and to increase lighted area of wall. A high reflectance exterior finish of reflector would greatly lessen the annoying feeling that it is an obstruction (large in visual size as reader looks up from work). Narrow band of specular reflection across front section of test plane, avoided when book tilted about 50°. About 8 ft-c additional light needed to increase upper wall brightness. Bronze outer finish, interior white enamel; two 15-w T-8 fluorescent lamps; 72-94 ft-c, average 80. Source brightness: 2500 ft-L; ratio direct to indirect illum.: 95:5.

Test No. (8) Right. One-inch decrease in base height would eliminate distracting view of inner reflector surface. Base position 2" closer to desk center will improve poor test plane distribution, although 15 ft-c on wall needed to reduce sharp brightness difference in wall pattern. Unavoidable sheen in small area left edge of plane. Bronze outer finish, inside white enamel; 32-w circular fluorescent lamp; 20-74 ft-c, average 49. Source brightness: 2300 ft-L; ratio direct to indirect illum.: 94:6.





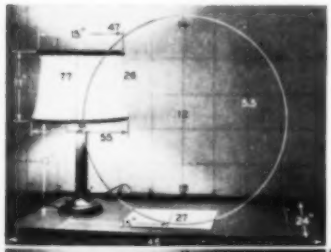
Test No. (9) Left. Base height allows a wide spread of light but with a lowered illumination level and with distracting view of wide band of inner shade. A three-inch decrease in height corrects these deficiencies and also results in a smaller area of specular reflection. A relatively large per cent of this area (23 sq. in.) reflects the inner shade at low brightness (av. 300 ft-L). Opaque shade produces large dark area on wall, relieved by adding 8 ft-c on wall. Tan opaque paper shade, white lined, on former certified I.E.S. specification study lamp; 100-w lamp in 8" blown glass bowl; 22-42 ft-c, average 31. Source brightness: 1400 ft-L; ratio direct to indirect illum.: 85:15.



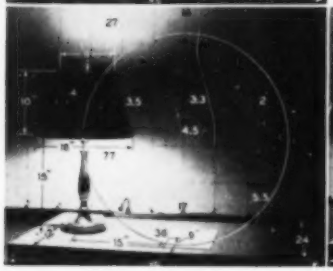
Test No. (10) Left. Provides relatively uniform test plane illumination. Level of illumination may be increased by lowering socket two inches and shade edge one inch. Position of lower edge of shade allows view of inner shade (325 ft-L) from 44" eye position. Opaque shade creates dark band on wall, requiring about 8 ft-c. to adjust brightness-ratio. Unavoidable specular reflection from 4500 ft-L source sufficient to reduce brightness contrast of print seriously. Medium reflectance opaque paper shade, white lined; 150-w R-40 white indirect-lite; 29-50 ft-c, average 38. Ratio direct to indirect illum.: 80:20.

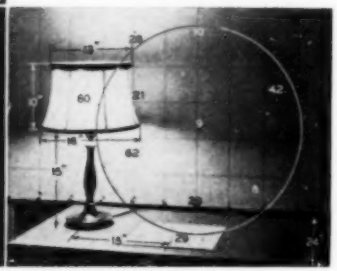
Test No. (11) Below. Translucent shades of moderate brightness are very effective in "smoothing" the brightness pattern of the wall. Additional lighting not required. No improvement over Test No. (10) in potential specular reflection. Lamp brightness reflected in shiny base, Tests No. (10) and (11), 82 ft-L. Off-white silk shade; 150-w R-40 white indirect-lite; 26-53 ft-c, average 39. Ratio direct to indirect illum.: 80:20.

Test No. (12) Below, left. This certified lamp of similar scale to that in Test No. (10) shows marked improvement in ft-c level, although not in uniformity of test plane. Shape and opacity of shade unfortunate in reducing indirect illumination on plane and in uneven brightness pattern on wall, needing over 10 ft-c additional to effect desired balance in wall area. The brightness of the bowl is roughly one-half that of the R-40 lamp, and its delivered ft-c at the point of specular reflection are greater so that its sheen does not reduce print visibility as seriously. Dark opaque paper shade, white lined; 50/150-w lamp in C.L.M.(C) glass; 28-81 ft-c, average 52. Ratio direct to indirect illum.: 92:8.



Test No. (13) Below, right. Larger top dimension and luminosity of shade show marked improvement over Test Lamp No. (12) in ratio of indirect illumination on test plane, in ft-c variation on test plane, and in wall-brightness pattern. The loss of ft-c in comparison to lamp 12 would be less with a lighter-colored shade. It is desirable to hold shade brightness to within three times that of test plane. The taller CLM table model in same position gives better distribution, a slightly lower level of light, but its greater height reveals under-shade brightness to eyes at 44" above floor. Deep rose-biege silk shade, white lining; 50/150-w lamp in C.L.M.(C) glass; 27-61 ft-c, average 42. Source brightness: 2250 ft-L; ratio direct to indirect illum.: 84:16.





ness is neither markedly *greater* nor *less* than the remainder of the field, it offers less attraction to pull the eyes to look directly at the luminaire. If the inner surface of the luminaire shade is visible, its streak of brightness can be most harsh, especially when the outer finish is dark. Design form and finish on luminaire bases should avoid the possibility of annoying reflection of the light source.

The brightness-ratios in the relaxing zone increase with luminaires having opaque shades and become intolerable when there is very little upward light. The easy prescription "use general lighting" is not a remedy for the more extreme situations. There is need for a more realistic viewpoint regarding the levels of general lighting now obtainable in residential rooms of even average size. Larger-scaled ceiling luminaires with greater lumen output than are now generally in use, or even available, are required in order to obtain wall illumination above 10 or 12 footcandles. In the 12′ x 12′ test room, for example, with higher than common reflection factors, a typical 150-w. silvered bowl adaptor in a central ceiling outlet supplies about 8 footcandles on the wall board located in front of the student.

Although lighting from other sources is always beneficial, a desk luminaire should and can, *with the prescribed situation*, provide substantially a 3 to 1 brightness ratio in the most important visual field without the addition of other room lighting. (Tests No. 1, 11, 13, 15, 16, 19, and 20.) Such a luminaire assures much better lighting for the vast majority of students who will not, do not, or may not be allowed to turn on other lighting in a room.

Control of Specular Reflection

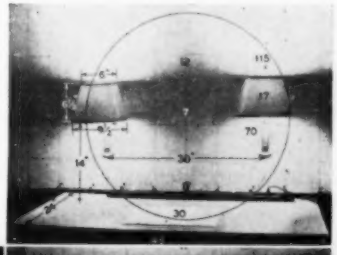
Every luminaire that was placed on or over a desk proved a possible source of specular reflection on the horizontal plane. When specular effect could be avoided by tilting the plane without undue loss of illumination, it is noted in the photograph captions.

As Test No. 1 proves, placing a luminaire directly in front of the student need not of itself always be unsatisfactory. The important considerations are light source brightness, footcandles, the area of specular reflection and its location on the work plane.

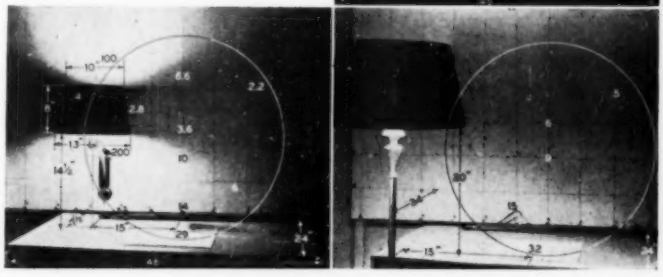
Placing the luminaire at the side, contrary to frequent assertion, does not avoid all potential reflected glare. It only reduces the area of luminaire

Test No. (14) Below, left. Certified (C.L.M.) wall model provides less even test plane illumination and more extreme brightness-ratios on the wall, especially with dark opaque shade—see Test No. (20). Ten ft-c additional needed on wall. Bracket cannot be hung closer to desk center without increasing unavoidable area of possible specular reflection (11 sq. in. left center). Center wall placement doubles the area of possible sheen. Dark opaque paper shade, white lined; 50-150-w bulb in C.L.M.(B) glass bowl; 20-72 ft-c, average 41. Source brightness: 2250 ft-L; ratio direct to indirect illum.: 89:11.

Test No. (15) Above, right. A pair of lamps obviously provides a more balanced illumination of desk and wall than a single table or wall model of the same type. Wall types free desk space and provide good distribution on desks 24″ or less wide. Higher transmission shades will improve wall pattern, although additional light from other sources not needed. Potential specular reflection in small areas on both sides of test plane. On 20″ x 38″ desks, book may be tilted to avoid specular reflection. The use of only one lamp, placed 12″ to left of test plane center, produces test plane variation of 4 to 1. Low transmission shades, light lined; 100-w lamps in 6″ plastic bowls; 30-54 ft-c, average 43. Source brightness: 2000 ft-L; ratio direct to indirect illum.: 83:17.



Test No. (16) Below, right. A floor lamp presents difficulty in placing correctly near left shoulder because of such frequent necessity to move it. Placed more practically and permanently at desk left, shade height above desk too high for 44″ eye position and test plane distribution poor. Placement shown requires 300 watts for recommended test plane illumination—no specular reflection except in small area when book tilted. Luminous shade improves wall brightness materially. Medium reflectance opaque shade, fabric on paper, white lined, 100/300-w. lamp in C.L.M.(A) glass; 37-70 ft-c, average 46. Source brightness: 2250 ft-L; ratio direct to indirect illum.: 80:20.



reflection. In order to eliminate it, the lamp has to be so far to one side that the illumination is inacceptably low; if the luminaire is pulled very close to the front, the annoyance is decreased.

Most books and magazines are far from flat, the surface wavers and presents various combinations of specular, spread and diffuse reflection. It will be evident that analysis by the use of the mirror does not represent the complete situation as regards area and brightness. When the specular area covers only a small proportion of the lighted page, moderate shifting of the reading matter will often move the annoying glare away from the center of attention. However, its presence is always annoying. Apparently it cannot be entirely avoided with typical desk luminaires, but there is no justification in study luminaires for source brightness that permits great reduction in the brightness contrast of print. Light from other sources and luminous areas is always helpful in diminishing the "punch" of specular reflection.

Visibility Level

Visibility level is one way of indicating[11] the suitability of the illumination for a seeing task. Visibility levels fall between 1 and 20, based on visual size of the detail and correlated with contrast between it and its background, and the work brightness. A visibility level of 1 represents barely seeing. A visibility level of 20 does not necessarily mean that the visual task is twice as easy to perform as it would be if its visibility level were 10. Table II sets forth visibility levels under various amounts of light.

The Society's recommendation of 40 footcandles for study is based on practical attainment with present day luminaires. It represents a visibility of 10 for 8-point size type printed in good black ink

Test No. (17) Top, left. Although scale of lamp suggests larger desks, its design and ineffective light spread require in-front placement annoyingly close to work center. Large area (30 sq. in.) of potential specular reflection and high brightness ratios are obstacles to comfort. Addition of 15 ft-c on wall will increase upper wall brightness to desired ratio with test plane. Bronze finish reflector, interior white enamel, curved stippled glass shield; two 15-w T-8 fluorescent; average 44. Source brightness: 2250 ft-L; ratio direct to indirect illum.: 95:5.

Test No. (18) Lower left. Lighting performance in general merits styling for home use. (See Fig. 5.) Shape of reflector permits hanging above view of student in reading position. Excellent distribution and favorable brightness pattern; better when unit 20" out from wall. Etched plastic or glass bottom plate advisable to reduce annoyance of shiny papers, even though the specular reflection is not sufficient to lower visibility materially, due to low brightness light source and high ft-c. It can be completely avoided by tilting book 35°. Medium gray metal asymmetric reflector with 1" slot cut in upper rear section for upward light, interior white enamel; two 20-w fluorescent; 55-101 ft-c, average 80. Source brightness: 1900 ft-L; ratio direct to indirect illum.: 83:17.

Test No. (19) Center. Shallow shades, possible with fluorescent lamps, reduce bulk of two table lamps. Lamp position, 3" above lower shade edge, cuts efficiency. Lowered $1\frac{1}{2}$", illumination increases to 56-68, average 62. Higher transmission shades and top-enclosing material desirable for more wall and upward light. Possible specular reflection at outer edges of test plane may be avoided by holding 50° tilted book at desk center. Shirred white fabric shades, obviously not supplied with bases, top enclosed with unlined stretched fabric; two 32-w circular fluorescent; 38-54 ft-c, average 44. Source brightness: 2050 ft-L; ratio direct and indirect illum.: 91:9.

Test No. (20) Right. A pair of Certified (C.L.M.) wall lamps with luminous shades provide brightness-ratios in good balance with favorable light distribution over entire desk top without additional lighting. Wide spacing minimizes area of possible specular reflection of both sides of test plane. At shallower desks, specular reflection may be avoided by tilting book 50°. White, low-transmission shades; 50/150-w lamps in C.L.M. (B) glass; 36-61 ft-c, average 48. Source brightness: 2250 ft-L; ratio direct and indirect illum.: 70:30.

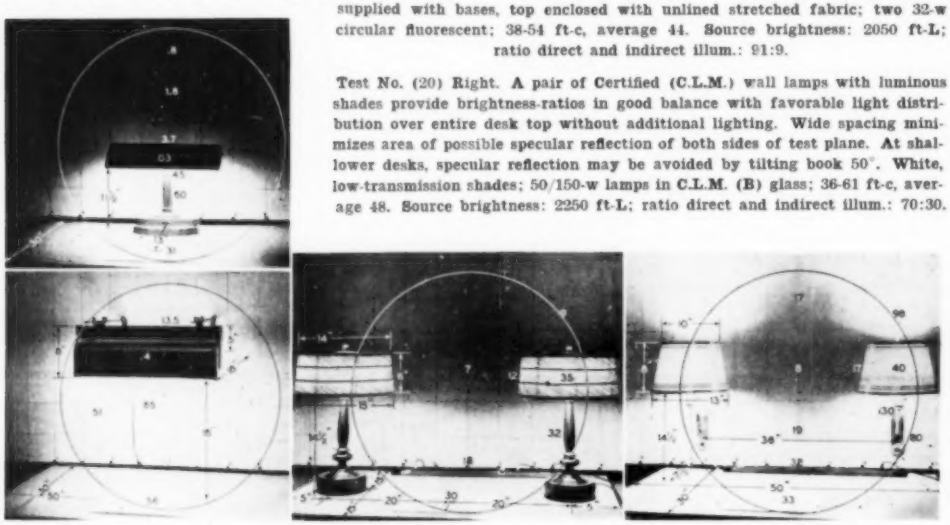


TABLE II

Visibility Level of Printing Under Varying Illumination (8-point Bodoni Type, 95% Brightness Contrast)

Footcandles on Type	Snellen Visual Rating		
	Normal	Subnormal	
	20/20	20/40	20/80
10	4	2	1
20	6	3	1.5
30	8	4	2
40	10	5	2.5
50	12	6	3
60	14	7	3.5
70	16	8	4
80	18	9	4.5
90	20	10	5

Data derived from "Footcandles for Critical Seeing," by Matthew Luckiesh and A. A. Eastman, ILLUMINATING ENGINEERING, Vol. XLI, p. 828.

on white paper, representing maximum brightness contrast.

Details of the same size having only 50% brightness contrast, such as penciled notes on poor paper, would have a visibility level of about 5 under the same lighting. This is equivalent to reading 6-point type, printed in black ink on white paper, typical of footnotes and the fine printing found on maps. These visibility levels obtain only for normal eyesight, and their relative reduction for the student with subnormal vision is seen in Table II.

Because of the increasing attention being given to visibility levels, the author studied the range of visibility levels (without specular reflection) for each luminaire. They indicate how well the footcandles provided by each are fitted to the study task. All luminaires except Test No. 9 provide an average of approximately 40 footcandles or better and thus a visibility level of 10 or better for 8-point type. However, in the case of Tests No. 2, 4, 5, 6, 8, 14, 16, and 17 there was a most undesirable change in visibility level from one section of the test plane to another due to non-uniformity of illumination. In Test No. 8, for example, the visibility level ranges from 6 to 17 (ft-c 20-74).

From the standpoint of vision, the seriousness of such marked change in visibility due to non-uniform lighting may be illustrated in a similar eye-disturbing situation. With a uniformly illuminated book, the same change in visibility level as for Test No. 8 would be experienced if the type in one section of the page were 13-point size (as in a child's story book) and graduated down across the page to 6-point size (smaller than newsprint). For Test No. 19, on the other hand, the more uniform illumination (38 to 54 ft-c) results in a minor change in visibility level from 9.7 to 12.8, which would be equivalent to slightly less than two points in type size.

The Photographs

The camera position and exposure were identical for every photograph. For a short period during each exposure, the light from a 150-w. silvered bowl lamp in a central ceiling outlet was added to help reveal wall detail. It is recognized that photographic prints and halftones cannot reproduce the range of brightness seen by the eye.

The figures on the photographs are footlambert values with the exception of those obviously describing luminaire dimension and position with respect to desk center and test plane. The circle aids in visualizing the extent of the most important visual field of the student when the eyes are raised from the book for rest periods, averaged for slight differences in sitting positions.

Conclusions

Home lighting techniques are being based more and more on technical knowledge. There is little need or excuse for continuing to fall back so often upon generalities. Through failure to analyze the facts upon which they are based, generalities are often misinterpreted. Specific recommendations, not generalities, can greatly reduce the wide gap that exists between present home lighting practice and the fine results which are within reach.

As a starting point, therefore, the author has selected the following basic guide posts from which good solutions may be devised:

1. Recognition of the need of a special location planned for study.

2. Provision of an ample size desk or table—preferably about 24" x 46"—with a dull finished top of 35% to 50% reflectance. Pastel blotters may cover the work area.

3. Positioning of eyes should be at least 14" above the desk top for desired distance to reading material. This requires attention to adjustment of chair height.

4. Placement of the desk flat against a wall. This position is perhaps not the most ideal psychologically, but it provides known and controllable boundaries of the visual field. When the wall is dark or strongly patterned, a framed tack board of 50-65% R.F. approximately 36" x 42" offers an inexpensive solution.

5. Recommendation of luminaires that:

(a) Provide at least 10% (and preferably more) of the illumination on the work area from the surroundings.

(b) Utilize high reflectance inner and outer surfaces of shades or shields. Luminous shades of parchment, plastic, or fabric should not exceed 100 ft. L on the outside.

(c) Supply at least 40 ft-c with no more than a three to one change in light level over a 12" x 14" plane when the luminaire is correctly placed. For standard desks and chairs and a 14" eye position above the desk, the lower edge of the shade must be no more than 15" above the desk.

(d) Incorporate light source diffusion with a source brightness of no more than 2500 ft. L and preferably less for the 40 ft-c level.

Few of the luminaires included in this study meet these specifications completely, despite their careful selection as representative of the best the market offers. They by no means represent the

millions of lamps being purchased today for study. Yet the millions of persons who attain the American level of education make the study situation a most important and ever expanding problem.

Figure 5 shows two experimental hand-made models of study-desk lamps which were developed as a result of these studies, as suggestions for further styling and commercial development. They indicate the possibilities of higher quality lighting for study than is provided by any single portable lamp on the market. As shown in the photo (Fig. 5, left), a single base could, at low cost, supply the desirable balanced lighting of two lamps. Essential to the design are a minimum distance of 22 inches between sockets (24" in this model), a height of 15 inches from desk top to lower edge of shade, 6-inch diffusing bowls, translucent shades, two 100-watt lamps, and treatment of the top of the shades to reduce glare when looking down into the shades.

The second design is planned for two 20-watt (or 15-watt) fluorescent lamps and uses plastic top and bottom shielding with arms adjustable for height and for distance from the wall in order to place it above the work center. This model could be developed either for hanging on the wall (with lightweight aluminum fittings) or for desk placement. A less dense plastic than is used for the shield shown could supply more upward lighting.

Acknowledgments

The author wishes to express her keen appreciation to Mr. E. W. Commery for his experienced guidance in method, selection, and interpretation of test detail; to Mr. Phelps Meaker for his suggestions for compiling data and editing the text; and to Mr. Harold Wachs for photographic art work.

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DISCUSSION

WALTER S. SMITH, JR.:* There is one item which seems important enough to call to your attention, and that is the omission of reference to the stroboscopic effect of fluorescent lamps and the importance of using corrected equipment. It seems to me that some notation should be made to the effect that tests 1, 5, 8, and 19 would not be comfortable because of the stroboscopic effect, especially with daylight lamps, and that tests 7, 17, and 18 would be more comfortable if stroboscopically corrected equipment is used.

With reference to test 19, which seems to have some very good qualities, especially when higher transmission shades are used, the thought occurred to me that it might be possible to get manufacturers to sell the lamps in pairs, stroboscopically corrected. It may not be practical, but certainly deserves consideration.

I realize that no one paper can cover everything, but in view of the fact that your paper will be widely distributed and used by manufacturers, utilities, and salesmen, I urge that you include in it references to the stroboscopic effect on visual comfort of single fluorescent lamps, as well as lamps operating from uncorrected ballast.

MARY E. WEBBER:** In the case of every lamp tested, I worked for several hours with each set up, and many of the lamps I used on my office desk for extensive periods. With none of the fluorescent models using 3500 white did I experience any bothersome stroboscopic effect. Normally very little desk work involves the rotation or rapid motion of objects required to create stroboscopic effect. Under these same conditions, I don't believe one would be any more conscious of this effect with daylight fluorescent lamps than with 3500°. The lamps in test 19 have been used for months on one of our desks, and the user has never been aware of any stroboscopic effect. I detected no difference in the light characteristics of the two tube luminaires in tests 7, 17, and 18, although the former two used individual ballasts and the latter a stroboscopic-correcting tulamp ballast.

*Georgia Power Co., Augusta, Ga.
**Author.

Errata—An important omission was made in one sentence of J. B. Bartow's discussion of the paper "The Lighting System for New York's New International Airport" published in the March issue of ILLUMINATING ENGINEERING. On page 149, the sentence beginning on the eighth line of the last paragraph, first column, should read—"Now, according to Allard's Law, for a steady source point of light that can be seen through 1000 feet of such a condition at night, the light would have better than 3.3 billion times 3.3 *billion times again 3.3 billion* candlepower." The words in italics had been omitted.

Since publication of his discussion of this paper, Mr. Bartow has had further opportunity to review his figures quoted in the next to the last paragraph of this column (page 149). He would like to acknowledge that the authors were correct, and to change his statements in this paragraph to: "The figures quoted pertaining to the approach lights as to candlepower, its visibility, etc., are interesting as to how they were arrived at, since they do not tally with accepted laws."

Design of Fluorescent Lamp Phosphors

By KEITH H. BUTLER

THE FLUORESCENT lamp industry is now ten years old. Since its start, major improvements have been made in the overall process of manufacture. Advances in lamp processing have led to improved life and lumen maintenance and advances in design and coating of cathodes have led to greatly improved life. In the field of phosphors, to which this paper will be limited, there have been major advances in initial lumen output, in lumen maintenance, and in color control. These advances are due mainly to improvements in what we might term "the art of phosphor manufacture." It is undoubtedly true that the scientific approach to phosphors was limited by the impact of the war on industrial research personnel, so that the art progressed more rapidly than the science. Within the past two years, however, sufficient information has been accumulated and sufficient investigations are underway so that we have a more scientific approach to the design of phosphors for specific applications than was thought possible even five years ago.

In the first fluorescent lamps, the phosphors used for white blends were limited to three components giving predominantly blue, green, and orange without any variation being possible in the color of these three components. As a result, the color of the fluorescent lamps, while approaching a white, could be controlled only roughly. We can now control phosphor colors very precisely by making minor variations in the spectral energy distribution of lamps. It will be shown that these minor variations within the spectral limits of 500 to 620 millimicrons are the important factors in determining the apparent color of objects illuminated by any broad spectrum light source, except in the case of dark blues and purples.

Requirements of Fluorescent Lamp Phosphors

One requirement of a satisfactory phosphor for fluorescent lamps results from the severe exposure to the effect of ultraviolet radiation of quite short wavelengths and also to the effect of ions in the arc stream. The phosphor must, therefore, have sufficient chemical stability to withstand these effects. Another requirement is that the

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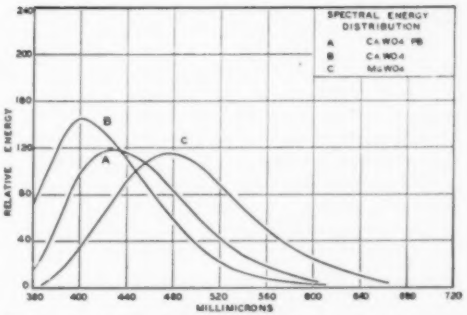

Figure 1. Spectral energy distribution of tungstate phosphors.

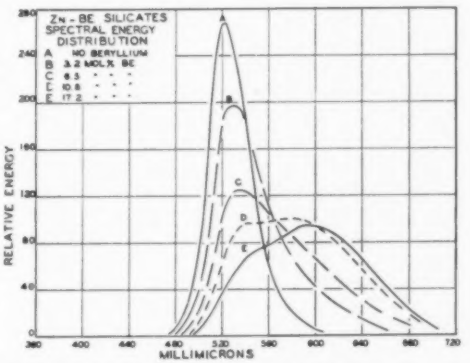

Figure 2. Effect of beryllium concentration on the spectral energy distribution of manganese activated zinc beryllium silicates.

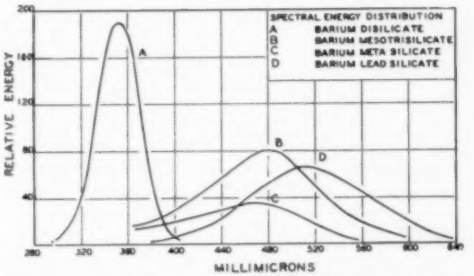

Figure 3. Spectral energy distribution of lead activated barium silicates.

particle size be sufficiently fine to allow proper adhesion of the powder to the bulb through the process of manufacture and subsequent use of the fluorescent lamp. A third important requirement is that the phosphor produce light of the desired color at extremely high efficiency, especially as compared to the incandescent lamp. A fourth requirement, which is of more direct interest to the manufacturer than to the ultimate consumer, is that the cost of the phosphor per lamp be as low as possible.

Phosphors without Activators

One class of phosphors used in fluorescent lamps, the tungstate phosphors, differs from other types in that no added activator is required to make the material fluoresce.

The first representative of this class is calcium tungstate which radiates in the near ultraviolet and blue-violet regions. The emission color of this phosphor may be shifted toward the blue by adding an activator, namely lead, which changes the peak of the spectral energy distribution curve from about 400 millimicrons to about 440 millimicrons. The second major representative of this group is magnesium tungstate which is used in practically all white* fluorescent lamps made at the present time. This phosphor has a spectral energy distribution peaking at about 480 millimicrons and is predominantly bluish-white in appearance.

The characteristics of the light emitted by these phosphors is shown in Fig. 1, where the relative energy is plotted against wavelength. These spectral energy distribution curves cover an extremely wide range of wavelength, that of magnesium tungstate spreading from 360 to 700 millimicrons. The curve is not symmetrical, rising more sharply on the short wavelength side than it drops off on the longwave side. If, however, we change the coordinate system so that the energy is plotted against the frequency, it is found that the energy curve is perfectly symmetrical and that its shape is that of a Gaussian probability curve.

Phosphors with Activators

Another class of phosphors useful in fluorescent lamps includes the silicate phosphors, in which silicic acid forms a compound with one of the metals in the second group of the periodic table. These phosphors, unlike the tungstates, must have a relatively large amount of activator present in solid solution in the crystal lattice. For an activator to be useful in a fluorescent powder of the type generally used in lamps, it must fulfill three requirements:

1. It must be soluble in the desired matrix up to high concentrations.
2. It must absorb efficiently ultraviolet radiation of 254 millimicrons. This second requirement is due to the use of mercury in the fluorescent lamp as the primary converter of electrical energy to radiant energy.
3. It must convert the incident energy of 254 millimicrons wavelength efficiently into visible light. It is found in practice that the color of the emitted light is determined by the particular activator and, while the color can be modified, only a rather narrow range of colors can be obtained with any one activator. Thus, lead generally gives longwave ultraviolet, blue, and blue-green emission, while manganese gives green, yellow, and orange emission.

In elementary chemisty years ago, it was taught that solids were composed of distinct molecules. Thus common salt contained molecules of sodium chloride, in which the sodium ion was linked to the chloride ion by some type of bond and these molecules formed the solid. In this model the molecules were the fundamental unit. The modern investigations of crystal structure by x-ray diffraction have upset this simple picture completely. Instead of individual molecules forming the solid, we find a three dimensional lattice structure in which each of the sodium ions is surrounded by and linked to six chloride ions, and similarly each chloride ion is surrounded by six sodium ions. Crystal structure terminology defines the number of surrounding ions as the coordination number of that particular ion — for example, sodium in sodium chloride has a coordination number of six. Experimental evidence is gradually accumulating to show that the coordination number of the manganese ion determines the location of the emission bands. In zinc silicate the coordination number is four and the emission color is green, while in calcium silicate the coordination number is eight and the emission color an orange red.

Manganese as an Activator

Managanese is an activator fulfilling the stated requirements in many instances and so is very commonly used. Thus, zinc orthosilicate can be readily activated by manganese and responds to 254 millimicron radiation with extremely high efficiency. This efficiency depends to a certain extent on the amount of manganese present.[2] With a low manganese content the efficiency is low and then passes through a maximum when the phosphor contains about .05 gram-atom of manganese for each gram-mol of zinc orthosilicate. With this amount of manganese, the color of light emitted is green and the emission band is extremely narrow as is shown in Fig. 2. As the manganese content is increased above this optimum value, the efficiency drops off slowly and there is a very slight shift in color toward a yellowish green. However, the apparent color is still green and the shift can be detected only by careful

*"White" is used as a generic term to include all colors lying on or approaching reasonably near the black body curve.

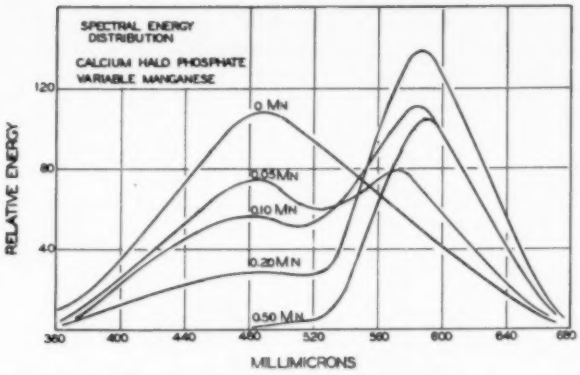

Figure 4. Effect of manganese concentration on the spectral energy distribution of calcium halophosphate.

observation or measurement.

The phosphor most commonly used at present in white fluorescent lamps is zinc beryllium silicate. The phosphor with no beryllium present gives a rather sharp emission band in the green. When beryllium is introduced as a replacement for part of the zinc, forming a solid solution in the crystal lattice, the color gradualy shifts from a pure green through yellow to a deep orange as the amount of beryllium increases. This shift in color has been the subject of considerable speculation and a new hypothesis explaining the color variation in terms of energy levels of the manganese ion in the crystal lattice was presented a little over a year ago.[1]

This theory suggests that the light emitted by the phosphor is composed of several superimposed bands and that each of these bands is due to a particular energy transition within excited manganese ions in the lattice. The location of these emission bands is related to the energy levels of the free manganese ion, which are affected by the other ions surrounding it in the crystal lattice.

Beryllium is a metal occupying a very low position in the periodic table. The atomic structure is very simple and the ion has a very small radius, approximately 0.3 angstrom as compared to the more normal ionic size of zinc and manganese which are about 0.9 angstrom. When this small ion is introduced into the zinc orthosilicate lattice, it causes a severe distortion of the electrical fields surrounding the various ions. As a result the probability of an excited manganese electron reaching one of its higher energy levels is considerably decreased. In reaching a lower level, the color of the emitted light becomes red rather than green.

In the zinc beryllium silicates, it is possible to change the color in two ways: (1) by increasing the manganese and (2) by increasing the beryllium content. Both of these are limited by the solubility of manganese and beryllium in the zinc orthosilicate lattice. Manganese can be substituted for zinc to the extent of 12 atom per cent and beryllium to 15 atom per cent. The effect of increasing either the manganese or the beryllium is to shift the color toward the red. A mathematical analysis of the emission curves has shown that the whole observed distribution can be explained by four or five separate but superimposed emission bands, each of these bands* being associated with a particular excited state of the manganese ion.[3] The possible variation in color is indicated by the spectral energy distribution curves in Fig. 2 where Curve A is zinc orthosilicate without beryllium and the other curves show increasing amounts of beryllium.

Lead Activated Phosphors

Another activator filling the requirements is lead and we have several examples of its use. Calcium silicate activated by lead is one of the most recent phosphors mentioned in the literature.[4,6] It can be excited by 254 millimicron radiation and emits long wavelength ultraviolet radiation between 300 and 400 millimicrons. The observed emission spectrum depends very considerably on the method of manufacture of this phosphor and it was demonstrated

*Each band has a Gaussian distribution when energy is plotted against frequency.

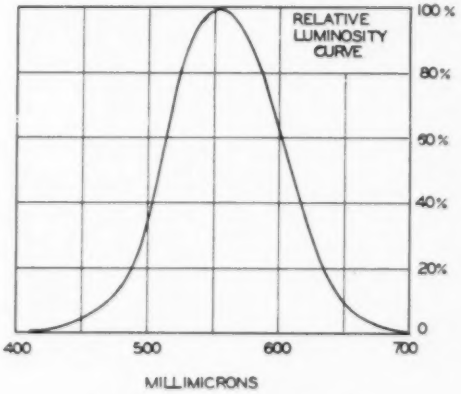

Figure 5. Relative luminosity curve.

that there were three separate emission bands—one peaked at 300 millimicrons, another at 350, and a third at 334. Each of these was due to one particular crystal form of calcium silicate—the first being due to the high temperature or α-form of calcium metasilicate, the second being due to the low temperature or β-form of calcium metasilicate, while the third is due to calcium orthosilicate. Unfortunately, the crystal structure of only one of these forms is well established — the β-calcium metasilicate in which the coordination number is eight. It is believed that the coordinate number of calcium orthosilicate is six.[5] From the emission band data we might predict a coordination number of four for the α-form of calcium metasilicate. Here again we may find evidence for the effect of coordination number of the activator ion on the color of the light emitted.

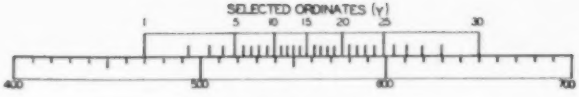

Figure 7. Spacing of selected ordinates for the luminosity function.

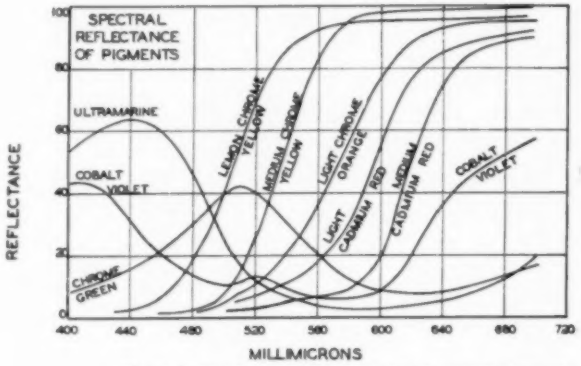

Figure 8. Spectral reflectance of some inorganic pigments.

Several phosphors based on barium silicates activated by lead have been described in recent literature. The first of these is barium disilicate which is activated by a very small amount of lead and emits longwave ultraviolet radiation.[6] It is thus similar to the calcium silicates above in its emission characteristics, although the crystal structure of the compound is entirely different and this difference results in higher efficiency of generation of the longwave ultraviolet radiation, which is desired. In addition to this ultraviolet emitting phosphor, a series of blue emitting barium silicates have been discovered.[7] These include barium metasilicate, barium mesotrisilicate, and a third compound which is thought to be a double silicate of lead and barium.

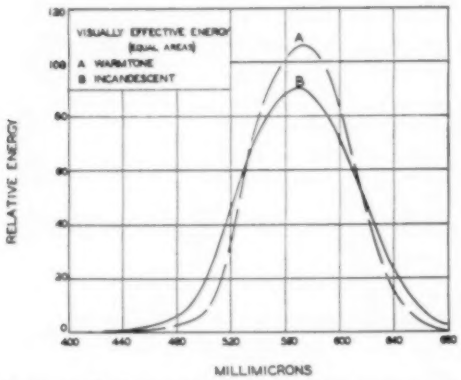

Figure 6. Product of luminosity function and spectral energy distribution for incandescent and for warmtone fluorescent.

The emission characteristics of all of these lead activated compounds is somewhat similar to that of the tungstates in that the emission covers a very wide range of wavelengths and if these emission curves are plotted on a frequency basis, it is found that the shape follows very closely that of the Gaussian probability curve. It is known that the energy level picture of lead is quite simple and the emission data indicates only a single excited level is possible for the lead ions in these phosphors. The emission curves of some of these barium silicate phosphors is shown in Fig. 3. The change in the location of the peak of the emission band is again felt to be due to variations in the coordination number of the activator ion, but no crystal structure data are available to confirm this.

Double Activated Phosphors

The fluorescent powders so far described have contained only a single activator which both absorbs the incident 254 millimicron radiation and converts it to energy of longer wavelength. In recent years, it has been found that certain compounds can be activated by a combination of two activators with the first activator serving to absorb the 254 radiation and the second governing the color of the emitting light. The outstanding exam-

ples of these are calcium silicate activated by a combination of lead and manganese[1,6,8,9] and calcium halo phosphate activated by a combination of antimony and manganese.[10] A third powder mentioned recently is tricalcium phosphate, activated by a combination of cerium and manganese.[11] In these fluorescent powders, the primary activator absorbs the incident 254 radiation and may emit light without the second activator entering into the reaction. If, however, the concentration of the second activator is sufficiently high, the absorbed energy is transferred within the crystal from the first to the second activator and the color of the light is then determined by this second activator. This effect is not readily recognized in the case of calcium silicate because the primary activator emits near ultraviolet radiation rather than visible light. In the case of calcium halo phosphate, however, the effect is extremely striking and the color of these powders can be shifted from a bluish white through white to pale yellow or even to a deep orange, depending mainly on the concentration of manganese present. The emission curves of some of these halo phosphate phosphors are shown in Fig. 4.

Phosphors Available for Lamps

Table 1 lists the major phosphors available for use in fluorescent lamps together with the location of the peak of their spectral energy distribution and their apparent color in lamps.

It should be noted that the width of the spectral energy distribution varies, with the tungstates being extremely broad, the lead activated barium silicates being only slightly less broad and most of the yellow and orange phosphors having rather broad distributions. In contrast, the spectral energy distribution of zinc orthosilicate is extremely sharp. With these phosphors we can form combinations having spectral energy distributions of almost any desired characteristics ranging from the relatively short ultraviolet through blue, green, yellow, orange and the near red. It is possible, therefore, to make fluorescent lamps in an infinite variety of hues and tints and this leads to the obvious question of standardization. What colors are desirable and how many should be made?

The light to which we are most accustomed, both natural and artificial, is of one particular type. This is scientifically described as a close approximation to black body radiation and the black body line on the I.C.I. color chart is well known. The exact location of the particular color on the black body line is described simply by specifying the temperature of the incandescent source. Thus, the ordinary tungsten lamp has a temperature of 2700°-2900°, photoflood lamps about 3400°, noon sunlight around 5500°, and north skylight about 10,000°K. It was natural, therefore, to use the black body curve as the first approximation to the desirable standard for fluorescent lamps. In this country we commonly use fluorescent lamps having color temperatures of 3500°, 4500°, and 6500°K, the last of these being called daylight. In European practice, it is rather common to use 5500° instead of 6500° as the approximation to daylight. Both of these colors are actually closer to sunlight in their spectral energy distribution than they are to true daylight as represented by light from the sky. The difference between European and American practice may reflect the peculiar psychological effect that a yellowish light makes one feel warmer than a cool or bluish light and since the European buildings are, in general, less well heated than American buildings, the warmer light is more appreciated. The opposite trend, namely, the choice of a cool or bluish light, becomes marked as we approach the tropics. Thus in Mexico the large demand is for 6500° daylight fluorescent lamps in preference to 3500° white.

Not long after fluorescent lamps were introduced, the feminine touch was felt and objections were raised to this new form of light because of its effect on appearance. To meet these objections, soft white fluorescent lamps were introduced. This color is definitely off the black body radiation line toward the purple and we can class it either as a purple 4500° white or a pinkish 6500° daylight. The same trend toward lamps with colors off the black body line is found in England where there is a tendency to use colors appreciably off the black body line toward the purple, the deviation being somewhat less than for soft white and the color temperatures being different.

Color Requirements of White Lamps

The question has been frequently raised, "What is the ideal white light?" An answer to this ques-

TABLE 1

Phosphor Base	Activator	Emission Peak, Millimicrons	Dominant Color Appearance
Calcium metasilicate (α)	Lead	300	Violet
Calcium metasilicate (β)	Lead	350	Violet
Barium disilicate	Lead	350	Violet
Calcium tungstate	None	400	Blue violet
Calcium tungstate	Lead	440	Blue
Magnesium tungstate	None	480	Bluish white
Calcium halo phosphate	Antimony	480	Bluish white
Barium lead silicate	Lead	500	Greenish blue
Zinc orthosilicate	Manganese	520	Green
Calcium halo phosphate	Antimony and Manganese	570	Blue white to deep orange
Zinc beryllium silicate	Manganese	600	Yellow to orange
Calcium metasilicate	Lead and Manganese	600	Orange
Tricalcium phosphate	Cerium and Manganese	640	Red

tion depends mainly on whether any other light sources are present in the field of view. The eye detects color differences effectively mostly by contrast with other colors. So, when only one light source is present, this source can have any reasonable spectral energy distribution covering the whole visible spectrum without it seeming unnatural as far as color rendition is concerned, since exact memory of colors is a very fugitive thing. Color contrasts are more readily remembered and a source may seem to give an unnatural rendition of certain objects with marked color contrasts.

Some physicists will claim that the ideal light source should have an equal distribution across the whole visible spectrum from 380 to 760 millimicrons as this source gives perfect color rendition. This equal energy spectrum is largely a theoretical standard as no practical source of light having this distribution has been developed. It should be fairly obvious that such a distribution will give a low overall efficiency value regardless of the phosphors used. The extreme ends of the spectrum have very low luminosity, and energy put into these ends of the spectrum gave us very little return in visibility. At the other end of the scale, some physicists have claimed that a green fluorescent or a sodium lamp is the most desirable light source since monochromatic light or a narrow spectral band gives the greatest visual acuity and the highest efficiency when at the middle of the spectrum.

Either of these extremes is usually undesirable so that a compromise between the efficiency of a selected monochromatic source and the perfect color rendition obtained with an equal energy source is indicated. This compromise must be influenced by the uses to which the source will be put. Its relation to other light sources in the field of view and the retained color contrasts are the principal factors. The distinction should be made here between the direct viewing of two light sources side by side and the viewing of objects illuminated by these light sources. It is perfectly possible to have two sources of an entirely different spectral energy distribution which are a visual match, but when these two sources are used for illumination of colored objects they may make these objects look vastly different. This difference will depend on the spectral energy distribution of the light, the spectral reflectivity of the object, and the general location of the color with respect to the luminosity curve.

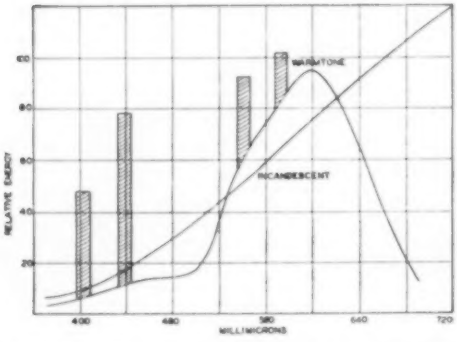

Figure 9. Spectral energy distribution of incandescent and warmtone fluorescent with uniform wavelength scale.

Evaluation of Lamps

In the evaluation of light sources, it is particularly important to take into account the variation of the sensitivity of the eye to different colors. Thus blues and reds have low luminosity compared to that of greens and yellows. In the discussion of phosphors so far, spectral energy distribution curves have been drawn with a uniform wavelength scale. We should now consider how these curves can be modified to take into account the luminosity curve, the shape of which is shown in Fig. 5. One way of including this luminosity effect is to plot the product of the luminosity function and the spectral energy distribution of the light source. This has been done in Fig. 6 for the fluorescent light from warmtone, (a "white" of approximately 3000°K), neglecting the mercury lines, and for the light from an incandescent lamp. In this figure the relative height of the ordinate at any given wavelength shows the effectiveness of the lamp at that particular wavelength. It is fairly obvious that this way of plotting is difficult to interpret and we should, therefore, look for some other way of representing the facts so as to accentuate the differences and the similarities between the sources.

In determining x, y coordinates for the I.C.I. color diagram from the spectral energy distribution curves, the method of multiplying the three chromaticity functions by the energy distribution is the well known weighted ordinate method and this is essentially the method used in setting up Fig. 6. There is another method used in determining these coordinates, the so-called selected ordinate method, where the observed energies at selected wavelengths are added. These selected ordinates for the y or luminosity function are shown in Fig. 7 and it will be seen that they are closely spaced in the center of the spectrum where the eye is most sensitive and far apart at the ends of the spectrum. Actually, the selected ordinates are placed at calculated intervals such that the product of the average luminosity between two successive ordinates multiplied by the wavelength interval between the ordinates is

always the same. So, for an equal energy source, the energy blocks contained between successive ordinates are of equal visual effectiveness.

Suppose we now place these selected ordinates at equal intervals and shift the wavelength scale to suit. Then we arrive at a wavelength scale which takes the luminosity function into account and using this scale the author has devised what might be called "visibility paper," which is useful in bringing out the differences or resemblances between various light sources. The purpose of this visibility paper is to emphasize the regions of the spectrum having high luminosity by giving them the greatest area on the plotted chart of spectral energy distribution. This important region between 520 and 600 millimicrons occupies the greater portion of the chart. The regions from 470 to 520 and from 600 to 650 are appreciably compressed, while the extreme ends of the spectrum are greatly compressed. Due to the method of shifting the wavelength scale, equal areas on the paper represent quantities of radiation of equal visual effectiveness. While this distortion may seem undesirable, a consideration of the characteristics of colored materials will show why it has certain definite advantages. These are especially apparent when we deal with the pastel colors often used in interior decoration.

Returning for the moment to the simple form of uniform wavelength scale, the spectral reflectivity curves for some pigment colors are shown in Fig. 8. We can see from these curves that most color distinctions are determined by changes in the amount of reflected light between 500 and 620 millimicrons. Thus, the curve for Lemon Chrome Yellow shows a greenish yellow, which reflects very little blue or blue-green light, reflects practically 100 per cent of the red light and shows a very sharp rise in the reflectivity near the green part of the spectrum. This general form of curve with a sharp rise in reflectivity is characteristic of most yellows, oranges, and reds with the difference between them being the point at which the reflectivity starts to rise rapidly. This sharp rise in reflectivity means that variations in the light source will cause little change in appearance of the color. It is rather surprising that practically all red pigments reflect the same amount of light beyond 640 millimicrons with the difference between a light red and a dark red being largely determined by the difference in reflectivity through the orange from 570 to 620 millimicrons.

In contrast to this general type of reflectivity curve we have a different type for the blues and greens where the reflectivity is low through most of the spectrum and there is only a gradual change extending over a rather large range of wavelengths. This difference in the two general types of reflectivity curve makes a difference in the behavior of colored materials under different light sources. Blues and greens are more sensitive to the energy distribution of the light source than are yellows, oranges, and reds when the colors are saturated. The situation changes when we have to deal with the unsaturated colors, that is, pastel shades formed by mixing white with the darker colors. In these light tints the reflectivity is more nearly constant through the whole spectrum and the apparent color even of yellows is considerably affected by the character of the light source. With all of these colors, the region of the spectrum of major importance is that between 500 and 620 millimicrons. In the case of purples, violets, and dark blues, the fine distinctions between these particular shades depend on the extreme ends of the spectrum, since they reflect very little light between 500 and 620 millimicrons. The common characteristic of these colors is the presence of a considerable degree of reflecting power for deep red light as well as for blue light, especially red beyond 640 millimicrons, and their appearance is determined by the relative amount of the red and blue components. Hence these colors are very sensitive to the energy distribution of the light source and are a particularly difficult problem for fluorescent lighting.

To compare light sources and their ability to blend when used together and to give the same rendition of colors, we can arrive at a general evaluation by plotting the energy of one source relative to the other on "visibility paper." If the curves are precisely parallel, the sources will blend perfectly. If there is a deficiency at one side of the center line, it should be balanced by an equal deficiency at approximately the same distance on the other side of the center line. Otherwise, the source itself will appear relatively off color and unsaturated colors will appear to be distorted. If sources are to be used together, the first requisite is that the curves be nearly parallel on the visibility paper between 520-600 millimicrons.

Combination of Fluorescent and Incandescent Lamps

Until recently the warmest fluorescent "white" lamp available was the 3500°K, which did not blend well with ordinary incandescent lighting. It was commonly thought that this inability to blend was due to the deficiency of the fluorescent lamp in the red end of the spectrum and much time and effort has been spent in a search for new red phosphors. During the past two years the general principles of color control and color rendi-

tion described briefly in the previous section were evolved. With this new understanding of principles, it was possible to develop a new fluorescent "white," the light of which blends satisfactorily with incandescent illumination.

The most important factor in obtaining such a blend of fluorescent and incandescent lighting is to have the energy spectrum of the two sources closely matched between 520 and 600 millimicrons. A slight excess of the red region of the spectrum is also desirable. Candlelight and fire light are still considered to be very flattering light sources due their warmth and any differences between a new fluorescent source and incandescent should therefore be weighted toward giving an excess of the "warm" or red region of the spectrum rather than allowing an excess of the cooler greens and blues. Beyond 600 millimicrons, fluorescent lamps have much less energy than incandescent lamps. Following another major principle developed in this study, this deficiency can be balanced by deliberately introducing a deficiency of the same order of magnitude in the blue end of the spectrum below 520 millimicrons.

In all fluorescent lamps, there is an extremely strong mercury line spectrum coming from the arc itself. The important contribution of this line spectrum to color rendition must not be ignored when designing phosphors for new fluorescent sources. The yellow and green lines must be considered first. Of these two lines the green is somewhat stronger and visually more effective. To balance out the effect of this green line, it is necessary and desirable to have the fluorescent spectrum somewhat lower than incandescent between 520 and 540 millimicrons and this lowering should be deliberately introduced for balance as well as for giving warmth to the light.

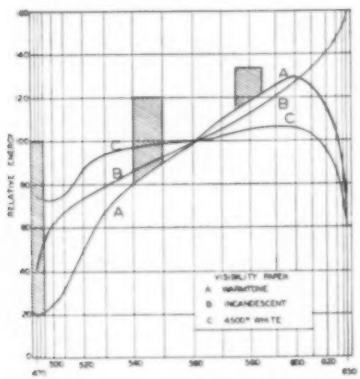

Figure 10. Spectral energy distribution of incandescent, 4500° white fluorescent and warmtone fluorescent on visibility paper.

The mercury line at 438 millimicrons is by far the strongest visible line in its spectrum and this makes a marked effect on color. This block of energy occurs at the point where the incandescent lamp is very low in energy and it, in comparison, introduces a strong excess of blue in the spectrum. Since it is not possible to balance this excess by introducing a similar excess in the far red, the only other solution is to drop the fluorescent spectrum well down between 400 and 510 millimicrons, so that the total energy up to 510 millimicrons will be approximately the same for fluorescent and for incandescent light.

The spectral energy distribution of the recently introduced warmtone fluorescent lamp, which follows the principles outlined above, is shown on a uniform wavelength scale in Fig. 9 in comparison with the energy distribution obtained from an incandescent lamp. This lamp has color coordinates very close to the black body line on the I.C.I. chart, approximately at the 3000°K point.

In Fig. 9, the energies of the mercury lines are shown as blocks of energy of 10 millimicrons width, one of the conventional ways of representing these monochromatic bits of energy. Fig. 6 has already shown the product of the energy distribution and the luminosity function, omitting the mercury line spectrum, for the same two sources.

A quick glance at either of these figures indicates a considerable difference between warmtone and incandescent light, but on closer examination it is seen that this difference is largely at the ends of the spectrum. If we plot the energy distribution on "visibility paper" the relatively close match in the visually effective middle portion of the spectrum becomes more readily apparent. This is seen in Fig. 10, showing the spectral energy distributions of incandescent, 4500° white fluorescent and warmtone fluorescent. To avoid confusion, the energy blocks representing the mercury lines are shown only for warmtone. The strong 438 line is roughly shown as an energy block on the left hand side of Fig. 10. Due to the location in the region of low luminosity, it is difficult to give an accurate representation of this line on visibility paper.

A comparison of warmtone with incandescent shows the fluorescent energy spectrum to be quite closely matched with the incandescent spectrum according to the principles outlined. With colored objects predominantly yellow or orange, there is a slight shift in apparent color toward the red as compared to incandescent lighting.

In this figure, it will be seen that the fluorescent light from the 4500° white, compared to incandes-

cent, is relatively lacking in orange and red and relatively high in blue and green. When the two sources are used to illuminate colored objects predominantly yellow, orange, or red, the distribution of energy in the 4500° source tends to shift the apparent color of the objects toward the yellow or greenish yellow. If, however, we make a comparison with the equal energy spectrum, represented by the 100 per cent line across the figure, it will be readily seen that the 4500° white is an excellent approximation to this distribution, with a deficiency at 480 millimicrons to balance the strong blue line and the lack of red.

Thus, we can see that the light from 4500° white is a good match for daylight or sunlight, which approach the equal energy spectrum, and will, therefore, give good color rendition for such comparisons. On the other hand, the light from warmtone fluorescent shows a good balancing of the energy distribution in comparison with incandescent light, when we again take into consideration both the luminosity function and the mercury line spectrum. The overall balance is such that the two lamps viewed directly blend well, and, in addition, when used to illuminate the neutral colors, white and grey, are almost a perfect match. The balance through the region between 520 and 600 millimicrons is sufficiently good to avoid any marked distortion of yellows, oranges, reds, and most greens. The deficiency in the far end and the strong mercury blue line combine to cause appreciable distortion of deep blues and purples. This distortion is considerably less than will be noticed when the same colors are compared by skylight, by sunlight and by incandescent light, as well as being far less than the distortion found with other fluorescent lamps. Due to the necessity of lowering the fluorescent spectrum between 400 and 510 to balance the blue mercury line, there will also be a slight distortion of certain pastel shades of blue green when compared with the results of incandescent lighting.

In the development of warmtone, the goal of developing a light to blend with incandescent light was the objective with two secondary objects being kept in mind: (a) that human complexions should seem natural and (b) that merchandise viewed under the fluorescent lamp should closely approach the appearance the same merchandise would have when taken home by the customer and viewed by incandescent light.

The major principle of color rendition, emphasized in the present paper, is that the spectral region between 520 and 600 millimicrons is the vitally important region.

With the fluorescent materials available at present, it is very easy to make minor changes in the fluorescent light emitted and it can be proved readily experimentally that such apparently minor changes affect the quality of the light greatly. If the amount of green is increased only slightly above that present in warmtone, the most striking effect is the sallow appearance of many human complexions. On the other hand, if the amount of green is decreased slightly, many colors, notably yellows, lose their "snap" or "sparkle" and merchandise loses its sales appeal. Thus the balancing of the light emitted in the high luminosity region is of major importance and this delicate balancing must be carefully controlled by accurate measurements on the phosphors.

Future Developments

The science of fluorescence is still only a husky growing child and major advances in our knowledge of phosphors can be expected in the years to come. With these advances in our fundamental knowledge we can expect further improvements in fluorescent lamps. Along with this basic technical development there is needed a corresponding development in the art and the science of color control and color application. For the past fifty years and more the only change in lighting readily available to the illuminating engineer and to the interior decorator was a brightness change. Color differences required the use of energy absorbing filters. These filters did not give precise control and were an expensive method feasible only for specialized applications, such as theatrical lighting. With the coming of the fluorescent lamp, we have a new tool, as the color of our lighting can be changed almost at will and certain portions of the spectrum can be emphasized or subdued. To make the greatest use of this new ability an extensive research study will be required as well as a general recognition of the fact that lighting is no longer shackled to the color of incandescent bodies.

If we succeed in this development, a wide advance in the application of fluorescent lamps, especially in home and store lighting, can be expected. This advance can be hastened if the principles of color control are developed and applied to the development of new fluorescent lamps designed to suit the new applications.

Summary

The developments in phosphors for fluorescent lamps during the past ten years are briefly reviewed and it is indicated that a very precise design of the spectral energy distribution of the emitted light is now possible. The effect of this energy distribution on the appearance of colored

objects is analyzed and a new method of presenting observed data so as to evaluate the luminosity function is suggested. The importance of the energy distribution between 520 and 600 millimicrons, as well as the effect of the mercury line spectrum is emphasized. It is indicated that inherent deficiencies in one part of the spectrum can be balanced by introducing deficiencies in another part of the spectrum.

The application of these general principles to the development of phosphor combinations, the light from which will blend with other illumination, is discussed in detail and the color properties and uses of warmtone and 4500° white are reviewed. The opinion is expressed that if full use is made of the possibilities of color control, as exemplified by these two new colors, the acceptance of fluorescent lighting will be based on a broader foundation.

Acknowledgments

It is a pleasure to acknowledge the assistance and advice received during the development of the warmtone lamp and in the preparation of this paper from Mr. O. H. Biggs, Dr. E. F. Lowry, Mr. R. G. Slauer, and other members of the Sylvania engineering staff.

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DISCUSSION

G. B. BUCK, II*: As indicated by the references cited by Dr. Butler, there has been relatively little on phosphor technology published in ILLUMINATING ENGINEERING although many papers on the subject are being reported in a number of other technical societies. The review of the literature and the outline of present practice given in the first half of this paper should bridge a considerable part of this gap in our Transactions.

In the latter half of the paper, the author describes a "visibility paper" he has "devised," which has ordinates spaced in accordance with the luminosity function of the human eye. He suggests this one function, which is one of the three chromaticity functions of the I.C.I. system, as the sole means of evaluating a light source as to its color matching or "compatibility" with another source.

The same "visibility paper" was presented[1] to this Society in 1922 by Dr. Frank A. Benford. He pointed out the applications for such "visibility paper" in permitting quick determinations of transmission or reflections factors by planimeter measurements.[1] Such a technique is valid and useful, partly because it is based on data expressed in absolute values. Efficiencies of sources could be evaluated in this manner if spectral data were presented on an absolute basis.

The luminosity function, only one of the tristimulus functions of the I.C.I. system, by no means provides a completely valid evaluation of color. One doesn't evaluate the quality of a cake by the amount of flour it contains. The flour is very important, it may be the bulk of the cake, but the other ingredients simply can't be omitted if one is to specify cake. Similarly, the spectral data for a light source must be considered in terms of all three of the I.C.I. functions if one is to define the color of that source and its relation to other sources. A totally color-blind monochromat or a partially color-blind dichromat may follow the same luminosity curve yet be quite unable to see color in the normal sense.

It is an interesting fact that the spectral emission curves of matching sources may approach or cross each other when multiplied by arbitrary constants and by the *Y*, or luminosity function, of the I.C.I. system; or when these data are plotted on a wavelength scale distorted by selected ordinates to give the same effect. Reference to the literature and my own checks do not substantiate the author's statement that the spectral curves must be parallel in the 5200°-6000°A region in order for the sources themselves to match in color.

Undoubtedly, one of the reasons the I.C.I. selected luminosity as one of the tristimulus functions was the fact that it permits a direct indication of brightness or reflection factor. However, if one considers only this function to evaluate illuminants, one disregards important differences in the color appearance of objects seen thereunder. For example, under an illuminant such as curve "A" Fig. 10, complexions appear somewhat greenish-yellow, as a result of the deficiency of blue and red. Whereas, soft white fluorescent, which has relatively less green, hence more blue and red, produces a healthy pink appearance.

The author states that, with this new "principle" of color evaluation, it became possible to develop the warm tone color to blend with incandescent illumination. It would be more accurate to say the color appearance of the fluorescent lamp itself was made to match that of the incandescent. The literature shows that with any given two or three phosphors, one and only one combination can give a color match to a specific light source. Hence, choice

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[1] F. A. Benford, "Plotting of Spectrophotometric Data," Swampscott Convention, *Transactions Illuminating Engineering Society*, Vol. XVIII, No. 1, p. 67 (January, 1923).

in "developing" a color match is quite limited and the only "control" available is in comparing one combination of phosphors with another. This basic technique of additive mixtures of light sources reached the level of international agreement by 1931 at the Paris meeting of the I.C.I.

Our first commercial fluorescent lamps of more than ten years ago were designed to match in appearance incandescent lamps at 2800°K. The above-mentioned color-rendering limitation — in fact the limitations of the filament source itself — soon became apparent in comparison with the superior qualities, for most applications, of the newer 3500° white, 4500°, daylight (6500°), and soft white lamps. There are, to be sure, some situations in which a color match of the incandescent sources and fluorescent as such may be desirable, just as there are many others where contrast is preferred. No doubt there are also situations in which the yellow or yellow-green emphasis by the warm tone fluorescent lamp is desirable.

Unlike the warm tone or warm tint, designed to color match a previous type of light source, the new soft white was designed for the optimum appearance of complexions, foodstuffs and materials of design and was based on long-range preference studies. In our I.E.S. paper[2] last year we presented the approach which places the greater emphasis on the optimum appearance of the environment. It was shown that one cannot in general have optimum appearance of materials or of the environment and at the same time match the color appearance of some other source as such.

KEITH H. BUTLER:* Mr. Buck has made some interesting comments on this paper, but his conclusions are open to question because of several misinterpretations of the text.

Mr. Benford's earlier use of "visibility paper" was limited to the determination of transmission or reflection factors and evaluation of materials. The present application, which was presented as a new approach to the study of light sources, does not suggest ". . . this one function . . . as the sole means of evaluating a light source" as Mr. Buck interprets the paper, but, as expressly stated, ". . . is useful in bringing out the differences or resemblances between various light sources." It was further indicated that in the case of purples and dark blues the ends of the spectrum were extremely important and that they represent a special problem. Mr. Buck fails to further to differentiate between the broad concept of compatibility with another source and the narrow one of color matching.

Mr. Buck has also misinterpreted the text when he says, "Reference to the literature . . . does not substantiate the author's statement that the spectral curves must be parallel in the 5200° to 6000°A region in order for the sources themselves to match in color." The actual statement, which refers to compatibility of sources, is "If sources are to be used together, the first requisite is that the curves be nearly parallel on the visibility paper between 520-600 millimicrons."

It is also an incorrect interpretation to say that the color appearance of the warmtone fluorescent lamp was made to match exactly that of an incandescent source. A simple comparison of the two sources would show this; while a color box comparison would indicate the two sources are almost a perfect match when used to illuminate white, neutral gray, or many other colors.

The question of color matches is confused by Mr. Buck's statement that only one combination of three given phosphors can give a color match for a specific light source. This ignores the possibility of using different phosphor components, and, by changing composition, varying the color of these components. With such phosphor variations several visual matches can be made for a given light source, which have quite different spectral energy distributions and consequently quite different color rendition. This variation of components was used in developing the warmtone color to give a fluorescent light source capable of blending well with light from incandescent sources by giving approximately the same color rendition as well as approaching the same color appearance when viewed directly.

As Mr. Buck indicates, ". . . the new soft white was designed for the optimum appearance of complexions, foodstuffs. . . . " This particular design was attained by suppressing the green and yellow components and emphasizing the red component of the light and when used alone it is therefore a very flattering cosmetic lamp. Even in this special application, it must be remembered that color schemes having a pleasing effect under soft white may not seem so pleasing under incandescent light. The ". . . healthy, pink appearance . . ." created under soft white may change materially under incandescent light. If we attempt, moreover, to use this lamp in combination with an incandescent source, it will be found that the resulting contrasts are nearly as unpleasant as those obtained when we attempt to combine 4500° white fluorescent lamp with an incandescent source.

From the theoretical standpoint, which Mr. Buck has chosen to take, it is possible to select a lamp color which gives optimum appearance of materials and of the environments. This lamp color is ideal so long as it is universally used and combinations of materials arranged under this single light source are always viewed under this same "ideal" light source. Unfortunately, the lamp manufacturer must consider the practical applications at all times and design light sources so that they can be combined with existing lighting without creating unpleasant effects. In the present paper, it was emphasized that the combination of two or more light sources in close proximity creates rather difficult problems for the lighting engineer unless the two sources blend well and the new warmtone color was specifically designed to blend well with incandescent light sources.

In addition to the possible combined use of two sources, it must be remembered that incandescent lighting still is the standard of comparison for home lighting effects. Merchandise purchased in a store must also appeal to the customer after he has taken it home and looked at it under an incandescent light source. As a hypothetical case consider an india print bought in a store under soft white light and used in the living room under a table lamp. The visual impressions obtained are as far apart as east and west and "never the twain shall meet." On the contrary, if the print were purchased under warmtone, the customer would have the same visual impression when the package was opened at home as was obtained when the goods were bought.

The warmtone fluorescent lamp, unlike soft white, is not a specialty lamp but rather a lamp designed to blend with incandescent lighting. Thus it finds direct application in homes, where the general illumination is that of incandescent lamps, and also in stores, where the general illumination may be fluorescent lighting, but where incandescent spot lights are widely employed.

[2] "Color Characteristics of Human Complexions," G. B. Buck, H. and H. C. Froelich. National Technical Conference, New Orleans, La., ILLUMINATING ENGINEERING, Vol. XLIII, No. 1, p. 27, (January, 1948).

*Author.

Studies in Gymnasium Lighting

By C. J. ALLEN
R. E. HOLMES

This paper reports a survey of 102 high school gymnasiums covering dimensions, activities, lighting and annual hours of use. Visibility studies made in well-lighted gymnasiums having fluorescent and filament installations provide a guide to recommended practice. Lighting layouts designed to meet the requirements of the multi-sport gymnasium are presented.

MENS Sana in Corpore Sano — a sound mind in a sound body. This old saying may be applied as a fitting inscription for the modern gymnasium, which is, indeed, a builder of sound youth.

Just what do we mean by a "modern" gymnasium? It might be defined as one which fulfills two principal requirements. First, it offers a pleasing and stimulating environment, which invites its use. Second, it provides facilities which are adequate to make the games and other activities enjoyable, for the players and for any spectators. Good lighting is an important factor in fulfilling both of these requirements.

Recommended Lighting Levels

The following minimum maintained lighting levels are recommended for high school gymnasiums:

Exhibitions and matches	30 Ft-c.
General Exercising	20 Ft-c.
Assemblies	10 Ft-c.
Dances	5 Ft-c.

For college games the minimum recommendation is 50 footcandles maintained in service. This level enables large crowds to see fast play clearly, and permits taking motion pictures for analysis of playing techniques. Some college gymnasiums are already wired to provide for double this recommended illumination.

Survey of High School Gymnasiums

A questionnaire on gymnasium facilities and activities was sent to high school administrators who had visited the Lighting Institute at Nela Park during the past two years. The 102 replies came from ten states, and from communities covering a wide and representative range of population. The findings:

(a) All the gymnasiums are used for general physical education, basketball, and school dances. In addition, 95 per cent are used for volleyball, 70 per cent for badminton, 50 per cent for indoor baseball, and 25 per cent for tennis.

(b) In three-fourths of the gymnasiums the school officials or coaches consider the lighting fair or poor.

(c) The one-quarter, in which the lighting is considered good, average 2.3 watts per square foot. Under typical conditions this wattage represents approximately 20 footcandles average in service. Fig. 1 presents the correlation between the judgments of lighting adequacy and the wattage per square foot.

(d) One gymnasium with 4.3 watts per square foot, corresponding to approximately 35 footcandles in service, is rated as "very good." This is the only one capable of providing the 30 footcandles recommended for high school games

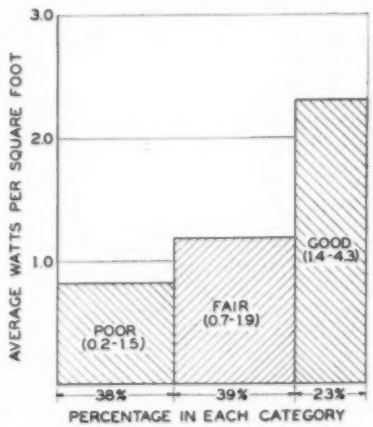

Figure 1. Correlation between average wattage and reported comments of school officials on the lighting systems employed in seventy-five high school gymnasiums.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Boston, Mass., September 20-24, 1948.
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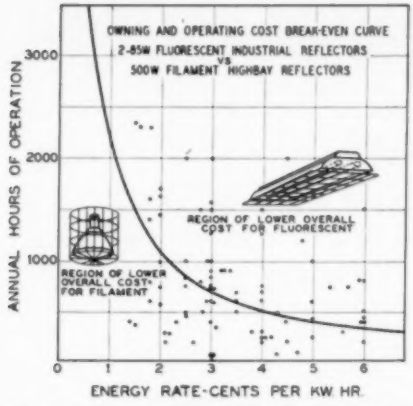


Figure 2. For the same light delivered, fluorescent lighting would cost less over-all than filament lighting in the majority of the gymnasiums surveyed. The plotted points show where the individual gymnasiums fall.

which are viewed by spectators.

(e) The hours of lighting use range from 100 to 2400 hours per year, with an average of 750 hours. The hours of lighting use for games with spectators range from 25 to 500 hours per year, with an average of 125 hours.

(f) In 55 per cent of the gymnasiums the combinations of energy rates and hours of lighting use indicate that fluorescent lighting would cost less overall than filament. Fig. 2 presents a curve of break-even cost for two gymnasium lighting systems, fluorescent and filament, delivering equal levels of illumination. The computations are based on equation (2) Appendix A, which takes into account both owning and operating costs.

(g) The average size of the gymnasiums in the survey is 82 feet by 56 feet, with a 21-foot ceiling.

(h) The average size considered "ideal" by those replying is 98 feet by 72 feet, with a 23-foot ceiling.

In regard to dimensions, the authors conclude from consultations with school officials and architects that a floor 96 feet by 76 feet has much in its favor. It will accommodate a regulation high school basketball court, 84 feet by 50 feet, with proper clearances all around and with seating capacity for 500 spectators in folding bleachers on one side. It will permit effective use of the floor for a variety of other sports. Hence these dimensions have been used as the basic gymnasium size in the lighting layouts presented later in the paper. Most larger gymnasiums employ the additional floor area principally for greater seating capacity.

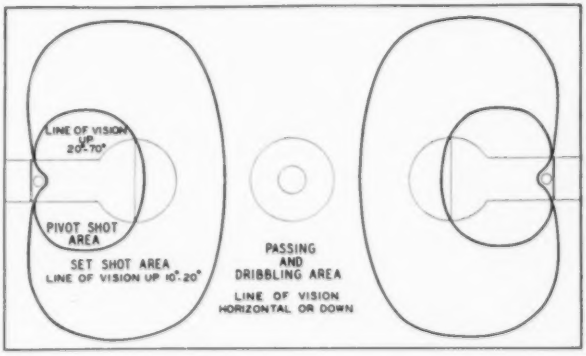
Basketball—Basketball play requires fast seeing. It is a game in which speed of vision is a factor both in safety of the players and in caliber of play.

Basketball might normally be thought of as an "aerial" sport—that is, one in which the ball is usually well above eye level. Actually, it is seldom an aerial sport except when the play is in close proximity to a basket. Fig. 3 shows the lines of vision characteristic of the various areas of a basketball court. In the passing and dribbling area, the ball generally travels below shoulder height. In the set-shot area the line of vision occasionally goes up to 20 degrees. In the pivot area, where the players look up toward the basket at 20 to 70 degrees or more, particular care is needed in positioning and aiming the light sources to minimize glare.

Visibility readings of a basketball were taken with a Luckiesh-Moss Visibility Meter[1] in two well-lighted gymnasiums having fluorescent and filament installations—Figs. 4 and 5. With the ball on and near the floor the readings of relative visibility were very similar in the two gymnasiums, ranging from 9 to 11. There was no significant difference in the measurements from the playing floor and from the stands.

Near the baskets, with the ball held stationary in the air 11 feet above the floor, the results were quite different. Values of relative visibility were 15 under the fluorescent lighting and, employing a special filter on the Visibility Meter, 160 under the filament lighting. This difference in values does

Figure 3. Illustrating the lines of vision characteristic of the various areas of a basketball court.


LINE OF VISION UP 20°-70°
PIVOT SHOT AREA
SET SHOT AREA
LINE OF VISION UP 10°-20°
PASSING AND DRIBBLING AREA
LINE OF VISION HORIZONTAL OR DOWN

not have direct numerical significance because the normal scale limit of calibration of the Visibility Meter is 20. Nevertheless, all observers concurred that the ball had far higher visibility under the filament lighting, as the readings attested.

The filament installation included two 500-watt high bay units located approximately 12 feet above and 3 feet in front of the basket. These put a high level of illumination in the region of the basket and backboard. In addition, they set up gradations of brightness on the ball which modelled it very clearly. The fluorescent installation, on the other hand, comprised rows of units lengthwise of the gymnasium with the baskets midway between rows. This layout did not build up the illumination level in the region of the basket and did not model the ball distinctly.

The ball was found to have maximum visibility when it was silhouetted against the brightness of a luminaire. When its silhouette was just tangent to a luminaire, on the other hand, the ball was hard to see. These variations in visibility were less pronounced in the case of fluorescent installations because of the lower brightness of the luminaires.

It was found that a light finish on ceilings, walls, and floor materially improves the visibility of the ball in contrast with its background, in addition to increasing the average illumination in the gymnasium. A light-finished ceiling is particularly helpful in making the ball more visible when it is in the critical locations where its silhouette is tangent to a luminaire.

The conclusion from these visibility studies is that fluorescent lighting may properly be used in gymnasiums where an overall cost advantage is gained or where the neater appearance of fluorescent equipment is desired, provided it is augmented with filament lighting in the pivot-shot area. This supplementary lighting is well provided by two high bay filament units placed 20 to 22 feet above the floor, approximately 3 feet in front of the basket and approximately four feet apart, and aimed directly downward. This position minimizes the occasions on which the units are close to the line of vision of the players.

Badminton—Badminton is strictly an aerial sport. The visual task of following the small, fast-moving shuttlecock is severe. Its light color can, at times, have a brightness similar to that of its background, with attendant low visibility. And if the line of flight of a "bird" passes in front of a luminaire the player may lose sight of it and miss the ensuing shot.

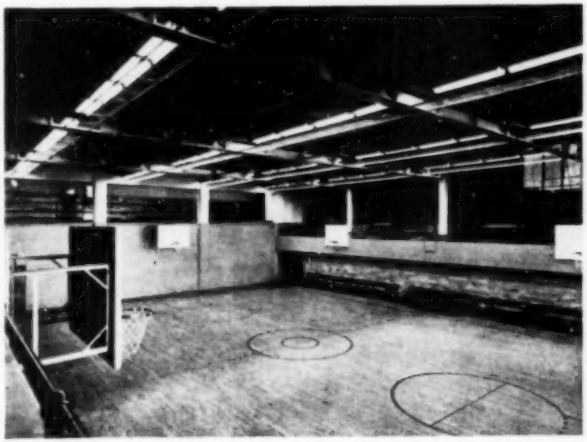
It may be concluded that ideal playing conditions are obtained when the bird itself is well lighted, its background is relatively low in brightness, and luminaires are removed from the normal lines of sight of the players insofar as practical.

Many forms of special lighting systems have been devised for badminton. It is beyond the scope of this paper to appraise them, because they are largely portable facilities which are not part of the permanent equipment of the gymnasium. It may be pointed out, however, that it is possible to obtain fairly good illumination for two or three badminton courts from the regular gymnasium lighting system. To get this result the layouts of luminaires and badminton courts must be properly coordinated, as in the designs shown later.

Badminton is often played where the bird is seen against light colored ceilings and walls, as recommended for gymnasiums. For such play the feathers can be treated with fluorescent liquids in brilliant colors such as fire orange and neon red. This will aid contrast and help maintain high visibility.

Dances—Since the survey indicates that all high school gymnasiums are used for dances, special provisions for appropriate lighting effects are warranted. A desirable atmosphere for dances is created by a low level of illumination—of the order of five

Figure 4. This McKees Rocks, Pa., gymnasium is lighted by continous rows of industrial reflectors 14 feet apart, each using three 40-watt fluorescent lamps. Calculated illumination 50 ft-c initially, 35 ft-c average in service.



footcandles—of a color flattering to skin tones. With fluorescent lighting the "soft white" lamps serve this purpose. With filament lighting the reflectors may be equipped with theatrical gelatin filters in a wide assortment of tints, and also in deeper colors for spectacular effects. Likewise, deeper colors may be obtained with fluorescent lighting by colored gelatin or cellophane sleeves.

Portable spotlights with color roundels, and portable fluorescent-lamp trough reflector units with an assortment of colored lamps, will enable dance committees to create distinctively interesting and original color effects.

Volleyball, Indoor Baseball, and Tennis—Volleyball, another aerial sport, is played with a relatively large ball which travels at moderate speed most of the time. Because of the lower brightness of fluorescent equipment, this game may be played with better comfort under fluorescent lighting than under filament lighting.

Indoor baseball and tennis are semi-aerial sports and hence also benefit by the low brightness of fluorescent lighting. Backgrounds of moderate reflectance at the ends of the court improve the visibility of the moving ball in silhouette.

Motion Pictures—The growing practice of analyzing basketball techniques and playing skill by means of motion pictures taken during the interschool games adds to the need for a higher lighting level. Fifty footcandles, the recommendation for college games, is considered a minimum for taking acceptable movies at a shutter speed of 32 pictures per second with a 1.9 lens and a fast film[2] (ASA 80). A speed of at least 32 pictures per second is preferred to the normal 16 pictures per second as the resulting slower motion produced when projected at 16 pictures per second permits more detailed analysis of the playing action.

An exposure meter is the simplest guide to a photographer wishing to know what pictures can be taken successfully in a specific gymnasium. The formulae in Appendix B may also serve as a guide.

Figure 5. Western Reserve University gymnasium, Cleveland, Ohio, has 500-watt filament lamps in high bay etched-aluminum reflectors spaced 8½ by 19 feet. Calculated illumination 45 ft-c initially, 30 ft-c average in service.

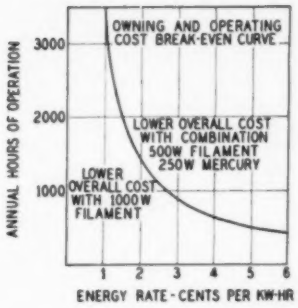


Figure 6. This chart may be used as a guide in determining where combination mercury-filament lighting has an overall cost advantage over filament lighting.

Combination Mercury-Filament Lighting

Mercury-vapor lighting, like fluorescent lighting, costs less overall than filament lighting under many conditions. Fig. 6 presents the curve of break-even costs applicable to gymnasiums.

The objection to mercury lighting, when used alone, is its bluish color which distorts the appearance of complexions. When filament lighting is used with mercury in sufficient proportion, the color objection is overcome. The general experience, in gymnasiums and more widely in industry, is that equal lumens of mercury and filament are fully satisfactory from the standpoint of appearance of complexions. To check this experience, a blonde and a brunette model were observed under 30 footcandles with a full range of proportions of mercury and filament lighting. The final judgments were then recorded as follows:

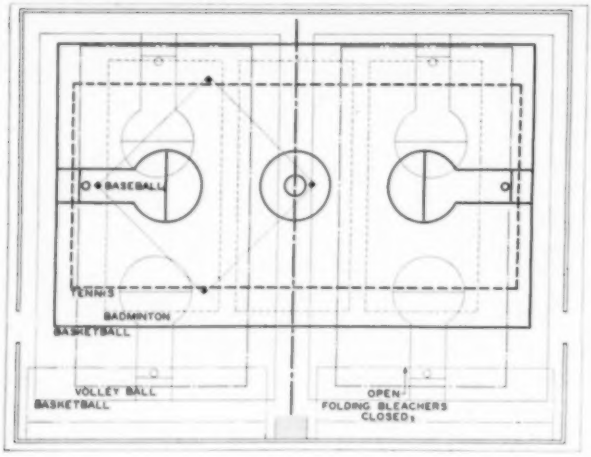


Figure 7. High School Gymnasium

	96′ x 76′
1 Standard High School Basketball Court	84′ x 50′
2 Physical Education Areas	72′ x 48′
2 Practice Basketball Courts	64′ x 42′
3 Badminton Courts (Doubles)	44′ x 20′
2 Volleyball Courts	60′ x 30′
1 Tennis Court	78′ x 36′
1 Softball Diamond	27′ x 27′

Lumen Percentages Filament	Mercury	Appearance of Complexions
100	0	Excellent
75	25	Good
50	50	Satisfactory
25	75	Undesirable
0	100	Objectionable

The conclusion is that *equal lumens* of mercury and filament lighting are a suitable combination for gymnasiums. Nevertheless in spectator areas it may be considered preferable to employ an illuminant which actually enhances the apearance of complexions, as already discussed for dances.

Stroboscopic Effect—Both mercury and fluorescent light sources, when operated singly on alternating-current circuits, produce a noticeable "flicker" on rapidly moving objects. It may be asked whether such flicker is of practical concern in mercury and fluorescent lighting systems applicable to gymnasiums.

Under fluorescent lighting with two-lamp ballasts, Reid and Michaels[3] reported flicker in fast table tennis at illumination levels in the range of 5 to 10 footcandles. They found no flicker at 50 footcandles and above. In experiments under such lighting at 20 and 30 footcandles, recommended for high school gymnasiums, the authors could detect no flicker on rapidly moving basketballs, tennis balls, shuttlecocks, or table tennis balls.

It is considered good practice, where mercury lamps are used alone in industry, to minimize flicker by connecting lamps on different phases or by employing two-lamp ballasts. With equal lumens of mercury and filament, flicker of fast-moving objects was found barely detectable—probably not enough to be of any practical consequences in a gymnasium. Nevertheless, the use of two-lamp ballasts is to be recommended in order to reduce installation cost and to improve power factor.

Interior Finishes

Light-finished ceilings, walls, and floors enhance the apearance of a gymnasium, besides increasing the illumination level and improving visibility as already pointed out.

Ceiling reflectances of 80 to 85 per cent are attainable on smooth surfaces with good grades of

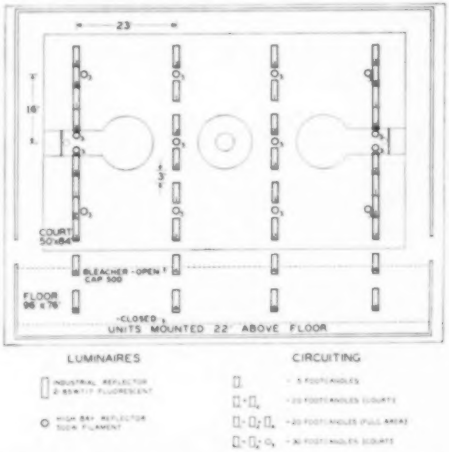


Figure 8. For high school gymnasiums whose operating conditions are economically suited to the use of fluorescent lighting, the suggested layout shown illustrates how a 5-20-30-footcandle level system might be installed.

white non-glossy paint. The same paints on acoustical materials have somewhat lower reflectances because of the porous nature of these surfaces. Perforated-type tile permits the maintenance of both good reflectance and sound-absorbing qualities when repainted, as the perforations tend to clog with paint relatively little.

Walls of matte-glazed tile or other non-abrasive material are widely used in modern gymnasiums up to a height of approximately seven feet. Above this area, light-colored cinder blocks, brick, or wood paneling provide a wall reflectance in the desirable range of 50 to 60 per cent.

Natural hardwood floors, sealed with a non-glossy finish, have reflectances of 15 to 30 per cent.

Maintenance

Over one-fourth of the gymnasiums in the survey had furred ceilings. This construction offers advantages of a neat ceiling appearance and usually easy access to the lighting equipment. Either filament or fluorescent luminaires may be mounted above ports in a furred ceiling, and lifted or tilted up for relamping and cleaning. The ports may be protected by wire mesh or by rigid louver assemblies.

With open-ceiling construction, luminaires suspended 20 to 25 feet above the floor may be serviced effectively from portable light-weight platforms. There are several designs which telescope or fold readily into compact form when not in use. For mountings above 25 feet there are larger designs of portable platforms; or disconnecting hangers may be used to permit lowering either filament or fluorescent luminaires to the floor for maintenance.

Dirt on luminaires, ceiling, walls, and floor may reduce substantially the level of illumination obtained initially. An adequate program of cleaning, relamping, and repainting is needed to insure getting the light paid for. Periodic measurements of the illumination with a light meter are valuable in establishing a maintenance program and checking its effectiveness.

Multi-Sport Gymnasiums

Fig. 7 shows a layout of the activities which can be accommodated in a multi-sport gymnasium 96 feet by 76 feet. The reasons for choosing these dimensions have already been explained. The multiplicity of lines may seem confusing on a plan view, particularly when all are in black. Experience in actual play has shown that with lines of different colors the players easily identify the boundaries of the game in progress.

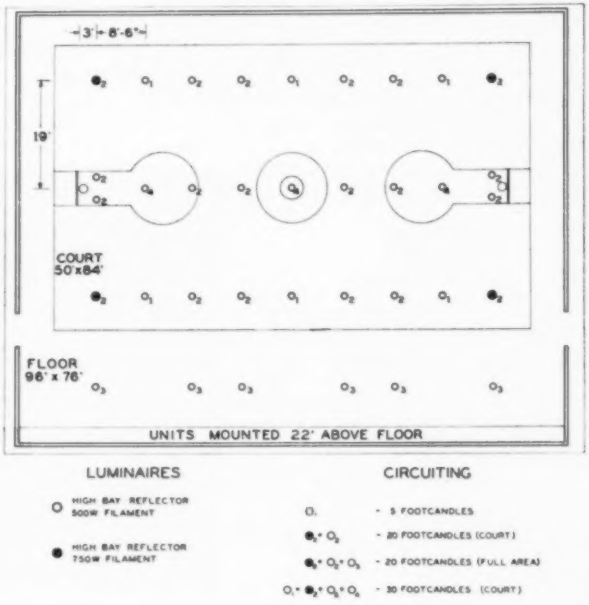
The lighting layouts in Figs. 8, 9, 10, and 13 have been worked out on the basis of the court locations in Fig. 7.

These lighting layouts assume the ceiling height of 23 feet indicated in the gymnasium survey. It is noteworthy that ceiling heights greater than 23 feet have two advantages — added clearance for aerial sports, and high mounting of the lighting equipment with attendant gain in uniformity of illumination.

Fluorescent Lighting

Fig. 8 shows a fluorescent lighting layout, employing 85-watt (formerly 100-watt) T-17 lamps in two-lamp industrial reflectors. The luminaires are circuited as indicated to provide five footcandles or 20 footcandles. The lower value—for pre-game illumination, dances, and other activities of a social nature—may well be provided by complexion-flattering "soft white" lamps. The entire fluorescent

Figure 9. For high school gymnasiums where energy rates and operation hours are relatively low, note Fig. 2, a filament system will probably be the most economical. This suggested filament layout provides 5, 20, and 30-ft-c flexibility for dances, general use, and exhibition events.



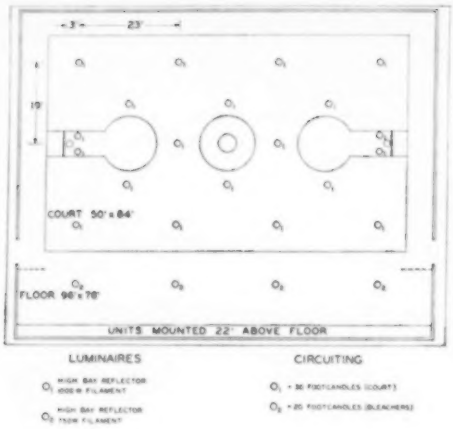


Figure 10. Suggested layout for 30 footcandles using filament equipment.

system, providing 20 footcandles, would be operated most of the time the gymnasium is in use. The uniformity of illumination is excellent.

The increase from 20 to 30 footcandles for games with spectators is obtained by supplementary 500-watt filament lamps in high bay medium-spread reflectors. The relatively short hours of use of this supplementary lighting do not usually justify the higher initial cost of fluorescent equipment. Note that two high bay reflectors with 500-watt lamps are located in front of each basket, as was found important in the visibility studies of basketball.

Prior to a basketball game, an illumination of 20 footcandles may be employed on the seating area with only five footcandles on the court. Then, after the spectators are safely seated the lighting over the seating area may be turned off and the full court lighting turned on, thus "setting the stage" for the game.

Filament Lighting

500-Watt Filament Lighting—A layout employing filament lamps in high bay medium-spread reflectors is shown in Fig. 9. Reflectors of etched aluminum have advantages of low brightness, ruggedness, and permanence of finish. All the reflectors employ 500-watt lamps except those at the corners of the championship basketball court, where 750-watt or pairs of 500-watt lamps are recommended. The uniformity of illumination is excellent. With circuiting as indicated, levels of 5, 20, or 30 footcandles are available.

Use of reflectors which will accommodate 1000-watt lamps, with wiring capacity for this wattage, is likely to prove a good investment. Simple socket adapters will provide the correct light center length for 500-watt lamps in these reflectors.

With filament lighting, one way to increase the illumination for exhibitions and games with spectators is to raise the voltage applied to the lamps. This may be done with variable-voltage auto-transformers or with transformers having over-voltage taps. When filament lamps are operated 10 per cent above rated voltage, for example, the light output is increased approximately 35 per cent; the wattage is increased approximately 17 per cent and the life is reduced to approximately one-quarter of rating.

1000-Watt Filament Lighting—Fig. 10 shows a layout employing 1000-watt filament lamps in high bay medium-spread reflectors over the champion-

Figure 11. Alternate 400-watt mercury and 750-watt filament units mounted 24 feet above the floor on centers 14 by 18 feet are used in this gymnasium in San Luis Obispo, California. Calculated illumination is 36 footcandles initially, with 23 footcandles average in service.

ship basketball court. A pair of 1000-watt lamps is recommended at each basket. The illumination level is approximately 30 footcandles in service, with good uniform distribution. Over the spectator area, 750-watt lamps provide slightly over 20 footcandles.

This layout offers minimum initial cost, but lacks the flexibility offered by the preceding layouts.

Filament-Mercury Lighting

A layout employing a combination of 500-watt filament and 250-watt mercury lamps in twin high bay units at a 22-foot mounting height is shown in Fig. 13. It is moderate in initial cost. With the filament lamps alone the illumination level is approximately 15 footcandles in service, with fairly uniform distribution. With both filament and mercury lamps in operation the illumination level is approximately 30 footcandles in service.

The break-even curve in Fig. 4 is a guide in deciding between the layouts in Figs. 10 and 13.

Alternate mercury and filament lamps of approximately equal lumens in high bay units give a satisfactory distribution and mixture of color where the spacing does not exceed two-thirds of the mounting height. For example, alternate 400-watt F-H1 (glass arc tube) mercury lamps and 750-watt filament lamps mounted 30 feet high on centers 16 by 20 feet will deliver approximately 20 footcandles in service. With the same layout, 400-watt E-H1 (quartz arc tube) mercury lamps alternated with 1000-watt filament lamps will deliver approximately 30 footcandles in service. This type of installation would be particularly applicable to college field houses and gymnasiums where high mounting heights may be obtained.

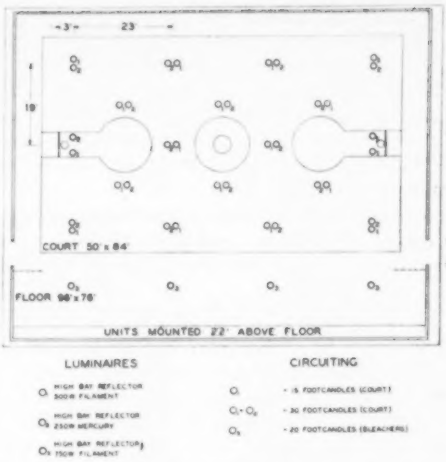


Figure 13. Suggested layout for 30 footcandles using combination mercury-filament equipment.

Summary

Most high school gymnasiums are not considered well lighted by the school administrators and staffs.

For high school gymnasiums the minimum recommendations are five foot-candles for dances, 10 footcandles for assemblies, 20 footcandles for general exercising and games without spectators, and 30 footcandles for games with spectators. Fifty footcandles minimum are recommended for basketball games in college gymnasiums. Data are presented comparing overall costs of filament, fluorescent, and mercury lighting for gymnasiums.

Figure 12. The Palestra, University of Pennsylvania gymnasium, Philadelphia, Pa., has 55 footcandles over the playing area with 1000-watt filament lamps in narrow-beam, high bay units. When these lamps are replaced with 1500-watt lamps operated at 10 per cent overvoltage, the illumination will be over 100 footcandles. Motion pictures are taken and games televised from platform above bleachers.

Fluorescent lighting has the advantage of low brightness of source and reflector. This is particularly important when the gymnasium is used for "aerial" sports.

Layouts are presented of fluorescent and filament lighting systems which meet the recommendation of three-step illumination levels for high school gymnasiums.

Layouts are also presented of filament and filament-mercury lighting systems which are low in initial cost but lack flexibility in illumination level.

Acknowledgments

The authors acknowledge indebtedness to the high school administrators and staffs who supplied data on their gymnasiums, to W. M. Councell for consultation on the visual requirements of gymnasium activities and for use of the Western Reserve University gymnasium for visibility studies, to officials of the McKees Rocks High School for use of their gymnasium for visibility studies, to members of the Illuminating Engineering Society's Committee on School Lighting and Committee on Sports and Recreational Area Lighting for consultation on details of the studies, to S. K. Guth for advice on procedure in the visibility studies and for measurements of visibility, to R. E. Switzer for assistance in experiments with the application of fluorescent liquids to badminton shuttlecocks, and to Kirk M. Reid for guidance in planning of the studies and presentation of the results.

Appendix

A. The annual overall cost of owning and operating a given lighting system may be determined by the following formula:

(1) $OOC = A + (H \times e) + (H \times r) + C$ where

OOC = Annual owning and operating cost of lighting system

A = Annual owning cost*

H = Annual hours of use

e = Cost of energy consumed per hour

r = Cost of lamp renewals (including labor) per hour

C = Annual cleaning cost

Using the above equation for comparing two systems providing equal illumination, the break-even hours or the annual hours of use (H) which will provide the same annual owning and operating cost may be determined:

$$(2) \qquad H = \frac{A_1 - A_2 + C_1 - C_2}{e_2 - e_1 + r_2 - r_1}$$

*An owning cost of 12½ per cent of the installation cost per year was assumed—covering interest on the investment, insurance, and amortization—in determining the break-even curves in Figs. 2 and 4.

B. The relationship between I, C, A, S, and T when

I = Incident light in footcandles (vertical)

C = 20; ASA calibration constant, incident light

A = Relative aperture or f number of lens

S = ASA film exposure index

T = Exposure time in seconds

required to photograph an average subject is given by the following formulae:

$$I = \frac{CA^2}{ST}; \; A^2 = \frac{SIT}{C}; \; C = \frac{SIT}{A^2}; \; S = \frac{CA^2}{IT}; \; T = \frac{CA^2}{SI}$$

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Applications of Low-Brightness Fluorescent Lamps

LEONARD V. JAMES:* It is noted that in several papers presented at the Conference, much has been said about the importance of designing luminaires which shield the lamps, so as to avoid unduly high brightnesses in the field of vision. One way to accomplish this desirable result would be to use only low brightness sources, such as the 40-watt T-17 fluorescent lamps. In many rooms it would be possible to use such lamps in troffers or in open top suspended luminaires which, by their side walls, shield the lamps crosswise of their axis but which provide no other baffles or louvers, and still satisfy the most rigorous requirements as to direct brightness. Reflected brightnesses would naturally be much lower than with the usual fluorescent sources.

Many illuminating engineers are aware of some very successful present installations of such equipment, while new luminaires employing this lamp are currently becoming available. That more consideration has not been given to such types is probably due to a possible erroneous idea as to their relative cost for the same level of lighting. Where the cost analysis allows for the much higher luminaire efficiency and maintenance factors which are possible, resulting in relatively fewer lamps required, and where the manufacturer has taken full advantage of the lamp characteristics in the design of the luminaire, this matter of relative cost may be found to be in favor of the low brightness lamp equipment.

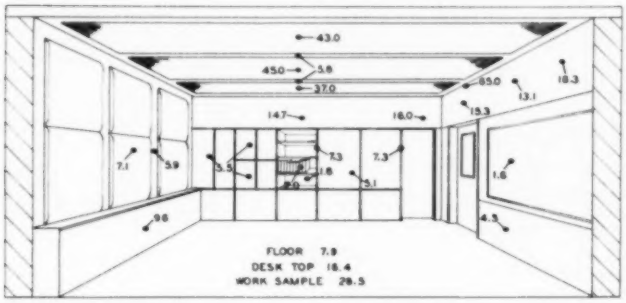
It is suggested that these possibilities be thoroughly explored by those who are responsible for recommending lighting installations for schools, offices and even high class industrial interiors.

*General Electric Company, Chicago, Ill.

Lighting a Classroom

LIGHTING OBJECTIVE: To illuminate a classroom by means of a louvered ceiling, uniquely providing a quantity and quality of illumination in keeping with the character of the installation.

BRIGHTNESS READINGS
LINCOLN SCHOOL, PARK RIDGE, ILLINOIS

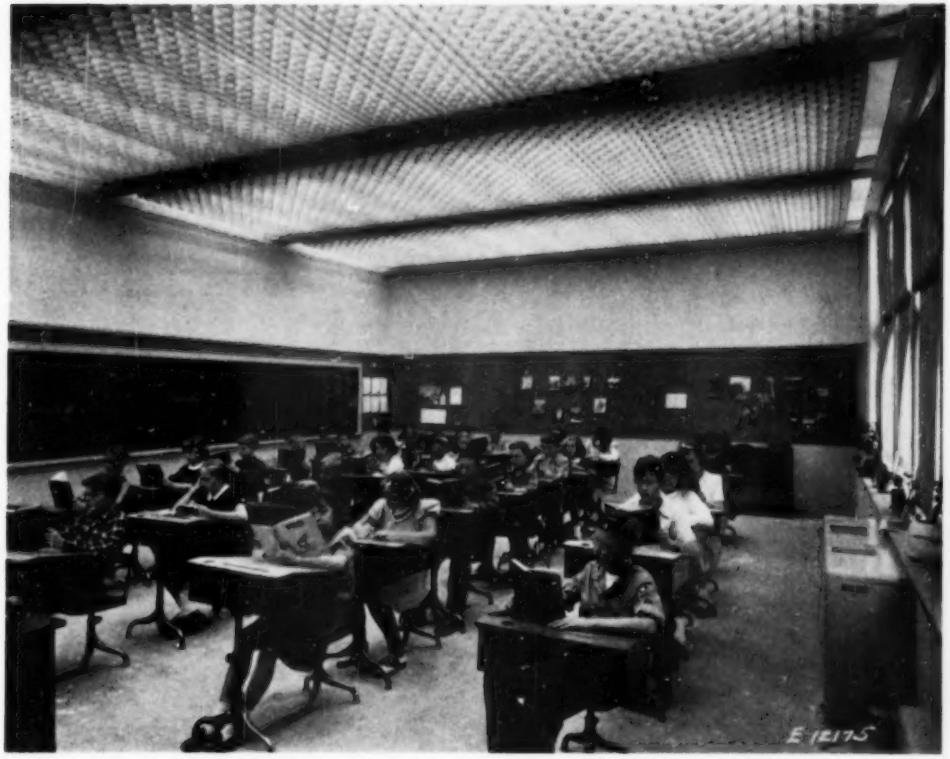


ALL READINGS TAKEN WITH SHADES DRAWN ON A DARKLY OVERCAST DAY.

Installation at Lincoln School, Park Ridge, Illinois

Perkins and Will, Architects

General Information: The room is 23 feet 10 inches by 34 feet 9 inches by 12 feet high. Room decorations are as follows: ceiling, white (85 per cent reflectance); woodwork on front cabinets, natural finish; all other woodwork light blue; blackboards, slate; upper wall and wall under windows, yellow (75 per cent); dado on wall opposite windows, light blue;



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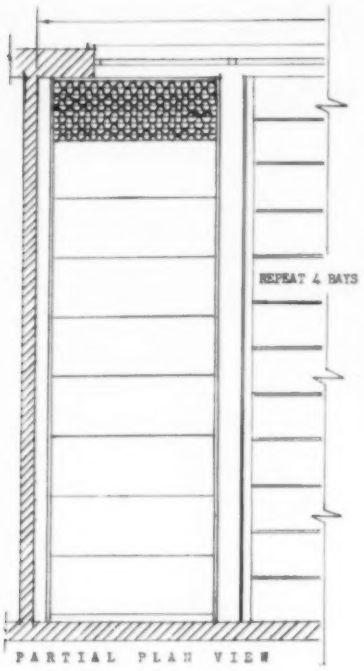

Installation detail

double roller shades, buff; desk tops, bleached wood (40 per cent); floor, variegated tan (35 per cent).

Installation: The ceiling is divided into four bays covered by louver panels 30 inches by 84 inches, made of venetian blind steel fabricated by Federal Electric Company. Four rows of 72-inch T8, 4500° slimline fluorescent lamps (300 ma), 11 in each row, are mounted $2\frac{1}{2}$ inches below the ceiling. The louvers are installed $11\frac{1}{2}$ inches below the lamps with the cells having a 22-degree cut-off lengthwise and 40 degrees perpendicular to the lamps. Four switches are used in order that certain portions may be illuminated as needed. An illumination level of 55 footcandles was measured after 400 hours burning. Brightness readings are indicated on the sketch. With the exception of the blackboard, the brightness ratios do not exceed 3 to 1.

Lighting data submitted by Arvid S. Almryde, Public Service Company of Northern Illinois, as an illustration of good lighting practice and to aid in the design of similar installations.

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Lighting a Cutlery Shop

A SHOP featuring cutlery as its only merchandise has store lighting problems all its own. Strangely enough, however, specific installations have seldom been published for cutlery stores.

An interesting solution of this application problem was recently made at the Exclusive Cutlery Shop in San Francisco. The illuminating engineer in charge of the job was Clifford L. Daly of the Pacific Gas and Electric Company of that city; Stanley E. Howatt worked out the layout.

As with most cutlery stores, almost the entire stock was on display in this small store, in dark-wood wall cases. For attraction of the customer and appraisal of the goods, some means was needed to highlight the merchandise and bring its detail out from the background.

With light-colored surfaces inside the dark cases, case lighting units with anodized aluminum reflectors were installed, using 40-w T-12 3500°K fluorescent lamps to provide 100 footcandles on the wall-hung merchandise. The highlights of the knives, scissors and other cutlery tools were immediately the brightest objects in the field of view—firs rule of attraction to displayed merchandise.

General lighting throughout the store was provided by two louvered units running the entire length of the room, using 6-lamp slimline 3500°K fluorescent lamps. The ceiling was painted a flat off-white of 80 per cent reflection factor; the upper walls were at flat cream of 65 per cent reflectance. Average general illumination is 45 footcandles.

The highlighted cutlery, lighted to 100 footcandles against the general background lighting, very effectively meets the recommendations for such areas—for attraction, appraisal and appeal.

Installation:
The Exclusive Cutlery Shop, San Francisco, California.

Equipment:
General Lighting — Two six-lamp slimline louvered units. Lamps are 3500°K fluorescent.

Case Lighting — Aluminum reflectors using 40-w T-12 3500°K fluorescent lamps.

Incidental Information:
Ceiling painted a flat off white, 80% R.F. Upper walls painted a flat cream, 65% R.F.

Lighting Levels:
Average general lighting, 45 footcandles. Case lighting, 100 footcandles.

Lighting Appointments on British Luxury Liners

IN HER postwar recovery plans, Britain counts heavily on her position as a carrier in the Atlantic tourist trade. As a symbol and instrument in this growing field of peacetime activity, the new 34,000-ton Cunard liner "Caronia" advances the best traditions of British skill in ship building.

While this new giant of trans-Atlantic travel is winning friends in her first season, an older ship, the 22,500-ton Furness-Withy liner, "Queen of Bermuda," has recently come back into the New York-Bermuda passenger service, completely refitted after a distinguished war record.

An outstanding feature of both the new "Caronia" and the re-fitted "Queen" is the reliance upon lighting to serve the comfort of the passengers and to present the richness of the decoration and furnishings with the fullest effect.

Lighting the "Caronia"

The lighting of this vast, superbly constructed vessel, is fully in keeping with other features of design which make the ship such an outstanding example of British skill and craftsmanship. The lighting, in fact, is so carefully integrated with the structure and decoration it unifies and heightens all appearance values. Thus the prevailing atmosphere of every public room is that of luxurious comfort. The many delightful effects represent the work of J. P. McBride of Messrs. McInnes Gardner & Partners, the architect responsible for design and decoration, with the collaboration of the British Thompson-Houston Company on the lighting features.

Lavish use has been made of veneered paneling in woods of rich variety, of engraved and sculptured glass and ornamental metal elements, of decorations in lacquer and gesso, of painting and sculpture. Flower boxes abound, lighted from soffits above. There is interesting diversity of satisfying color harmonies in draperies, rugs, and other appointments. Most of the interior surfaces are light enough to afford an agreeable visual environment.

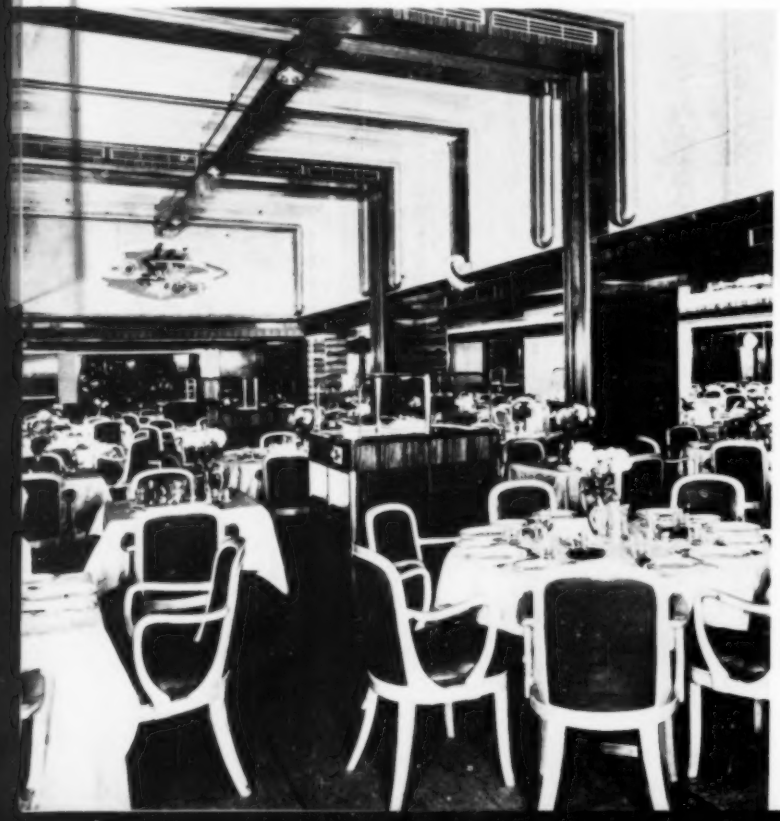


Figure 1. Balmoral Restaurant on the "Caronia" makes extensive use of multiple fluorescent lamps concealed in coves and golden metal troughs to enhance the appearance values of the quilted birch veneer panels in the upper walls and ceiling. In the lower sections at the side, lighting is from continuous glazed cornice together with spot lighting of the individual tables from flush fittings.

In each of the "Caronia's" main public spaces, a combination of standard multiple fluorescent and filament lighting is employed to provide illumination of character and quality consistent with the appointments and color schemes. Concealed warm-white fluorescent lamps, and in some instances tinted glass, contribute to the charm of the dominantly sunny atmosphere.

One of the ship's restaurants, illustrated on these pages, is an example of the way the designers have combined lighting and decoration. Since the restaurants represent the more elaborate efforts in appointments, especially with respect to the uses of rare wood and metalwork finishes, the lighting schemes are proportionally lavish.

The garden lounges are among the numerous other attractive public spaces, each distinctive and developed with imagination. Here an impression of sunlight has been created to heighten the effect of tropical plants and flowers. In the evening these garden lounges are peak attractions.

Throughout the passenger decks on the "Caronia," wherever the traveler goes, he finds handsome settings more delightful because of care in the lighting plans.

Lighting the "Queen of Bermuda"

The illumination for this fine ship has been entirely renewed. Over 80 designs were prepared in the Fittings Design Office of the General Electric Company, Limited to provide lighting installations suitable to the furnishings of the "Queen." Messrs. McInnes Gardner & Partners of Glasgow were the decorative architects for this ship, also.

Cold-cathode fluorescent tubing, aggregating nearly three-quarters of a mile in length, is used for most of the public rooms. Most of the tubes are applied in indirect cornices. A 230-volt AC supply is provided from two rotary converters operating on the ship's 230-volt DC system. A third converter is available as a standby machine.

Figure 2. Above. Panel at end of the First Class Main Lounge (Caronia) is veneered in pale golden mottled Canadian maple, divided into squares with a sunken "V" joint. Chairs and settees are covered in harmonizing green, peach, and fawn.

Figure 3. The sunlight environment of the Garden Lounge (Caronia) is produced by combining warm-white fluorescent and filament components. The former is used in continuous ceiling coves, the latter in recessed downlights and in soffits over tropical plants and flowers.

Figure 4. Luminous ceiling panels lighted by concealed cold-cathode tubing emphasize structural features of this cocktail lounge on the "Queen." Filament downlights build up illumination in the area near the service bar.

Dining rooms on the "Queen" follow the precedent of appointments for famous passenger levels with the most pretentious furnishings. In the First Class dining salon, most of its area is lighted by an indirect system. Warm-white and gold tubes in cornices comprise the main elements of the illumination. Additional tubing is used in a glazed cornice in the center of the ceiling well. Then at either end of the room there is a decorative ceiling unit which emphasizes in its elongated form the structural pattern of the space.

The First Class Lounge on "A" deck (see illustration) presents one of the "Queen's" most interesting installations. Here there is a combination of fluorescent tubing and filament lighting. Warm-white tubes are concealed in a cornice running around the center of the room, and in a number of ceiling panels in the wings. The central portion of the ceiling contains a "skylight" equipped with filament units in reflectors. Four ornamental, silver-plated torchieres, glazed with pink tinted glass, and equipped with filament lamps add a note of opulence to the lighting contribution in this lounge.

Figure 5. The Main Lounge of the "Queen." Upper walls are kept luminously in key with "skylight" panels, the former lighted by means of concealed fluorescent sources, the latter from filament units. Handsome torchieres sustain the luminous decorative feature at floor level.

Correction of Light-Sensitive Cells for Angle of Incidence and Spectral Quality of Light

By G. B. BUCK, II

Optical characteristics of light-sensitive cells of the photovoltaic (barrier-layer) type are discussed. A new lamination technique is described by which the inherent errors in color and angular response of the cell may be corrected at much higher efficiencies than hitherto attained. Performance characteristics of these laminated cells are given and requirements are discussed for field and laboratory instruments for the measurement of light intensity. A pocket light meter for general field service, a low-range precision instrument suitable for street lighting measurements, and a multi-range precision instrument which utilize laminated cells are described.

THE fluorescent lamp has provided a new horizon of opportunities for the entire lighting industry. At the same time, it has presented several new problems. Perhaps one of the simplest of these, and yet one which has thus far escaped a completely satisfactory solution, is the measurement of light intensity from fluorescent lighting systems.

Prior to the fluorescent lamp, the selenium photovoltaic, or "barrier-layer" cell was developed and applied to the measurement of illumination in the field and in the laboratory[1, 2]. Since this type of cell produces an electric current in proportion to the amount of light absorbed, it became a simple matter to connect a suitable microammeter with such a cell to form a light measuring instrument. Several variations of the basic design have been developed, each representing a compromise between the required sensitivity and precision, cost, ruggedness and size, to meet specific needs. Perhaps the most commonly known and widely used is the "Light Meter" form of instrument, Fig. 1, in which nominal sensitivity and precision are accepted in order to achieve small size and ruggedness.

Spectral Response

At an early date, it was established that the response of the selenium cell to various wavelengths of light differs considerably from that of the average human eye, Fig. 2. The curve for the average eye is the "Standard Observer" as defined by the International Commission on Illumination, (1931)[3]. At the time, this difference was of little practical significance, except for the measurement of daylight, since there was but one common interior illuminant, the incandescent lamp. Meters were calibrated under this source, which has so little variation in spectral emission over the range of sizes, wattages and filament temperatures encountered,[4, 5] that the error is negligible within the accuracy required for field and most laboratory instruments.

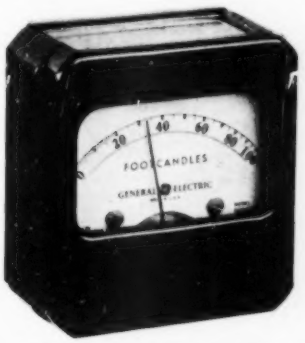


Figure 1. Pocket light meter incorporating a selenium photovoltaic cell and a microammeter.

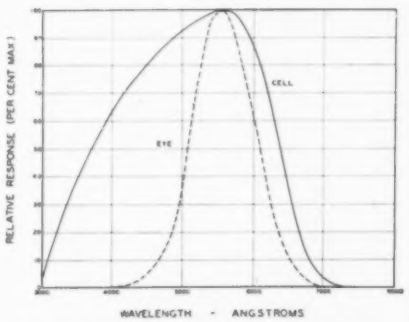


Figure 2. Relative response of the average human eye and average light meter cells of recent production to various wavelengths of electromagnetic rediation.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Boston, Mass., September 20-24, 1948. Mr. Buck is with the General Electric Co., Nela Park, Cleveland, Ohio.

Nevertheless, such meters were not suited, per se, for the measurement of discharge sources since these differ greatly from the filament calibration source in spectral emission. Nor is the filament lamp calibration valid for the measurement of natural daylight, the spectral character of which

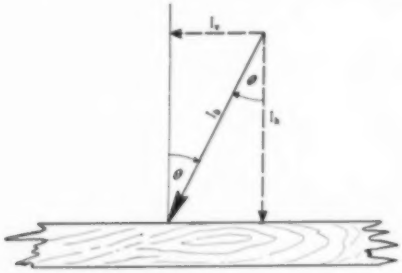


Figure 3. Vector diagram illustrating Lambert Cosine Law. Surface illumination is product of beam intensity and cosine of the angle (θ) to the normal.

TABLE I—Correction Factors for Selenium Photovoltaic Cells* under Various Light Sources

Source	Color	Correction Factor	
Incandescent	2700°K	1.00	1.02
	2800	0.99	1.01
	2900	0.98	1.00
	3000	0.97	0.99
	3200	0.95	0.98
	3400	0.94	0.96
Fluorescent	White (3500°)	1.04	1.07
	45 White (4500°)	0.94	0.97
	Daylight (6500°)	0.84	0.86
	**Soft White (A)	0.87	0.90
	(B)	0.95	0.97
	Photocolor	0.76	0.78
	***Warm White (2800°)	1.02	1.04
	Warm Tint	1.06	1.08
	Blue-White (RF)	0.77	0.79
	Industrial White (RF)	0.79	0.81
	Blue	0.46	0.47
	Green	1.45	1.48
	Pink	0.93	0.96
	Gold	1.27	1.31
	Red	0.68	0.70
	360-BL	0.07	0.07
Mercury	AH-1	1.05	1.07
	DH-1	0.84	0.86
	EH-1	0.94	0.96
	AH-4	0.86	0.88
	AH-5	0.93	0.96
	H-6 (Quartz Jacket)	0.66	0.68
	(Glass Jacket)	0.70	0.71
	H-9	1.02	1.04
	UA-2	0.78	0.80
	UA-3	0.76	0.78
	UA-4	0.83	0.85
	Germicidal (18T8)	0.58	0.60
Sodium	NA-9	1.36	1.40
Neon	15 mm. tubing at 30 ma.	0.85	0.87
	Hot Cathode (C-H)	0.83	0.85
	Glow Lamp	1.09	1.11
Carbon Arc	Cerium Cored (50 V. 60 Amp.)	0.48	0.49
	Low Intensity (140 V. 14 Amp.)	0.31	0.32

*Computed for Light Meters (G-E) of current production, from most recent data available on spectral emission of sources.
**Soft White (A), prior to April, 1948; (B) after April, 1948.
***Color discontinued in 1944.

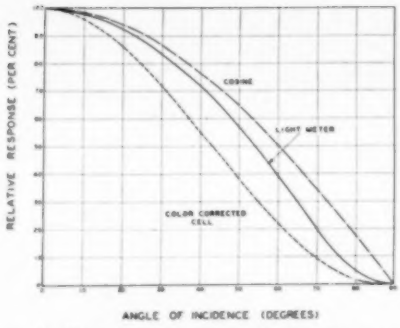


Figure 4. Chart indicating theoretical cosine response (dashed curve); angular response of light meter (glass-covered selenium cell) (solid curve); and angular response of cell color-corrected with glass filters, (dotted curve).

differs from filament and also varies from hour to hour, day to day and seasonally.

At this juncture, the fluorescent lamp was introduced in many new hues and purities of color, each with a spectral distribution of energy emitted differing widely from its fellows and differing from incandescent lamps.[6, 7, 8, 9] Almost immediately, it was found that available light measuring instruments calibrated for filament lamps were seriously in error and it became common practice to use "correction factors". Such a factor is needed for each color of fluorescent lamp, as well as for the other discharge sources, in order to convert the scale readings to true footcandle values. While each manufacturer made available tables[10] of correction factors for each light source, including mercury, sodium, etc., it is easy to misplace such tables and the mere need for correction factors tends to limit the use of these instruments. Furthermore, the wide variation in color of natural lighting and the light reflected from colored walls makes a simple correction factor for such measurements virtually impossible.

Table I presents correction factors* computed for the spectral response of light meters of recent production when used under the indicated light sources. The values in the first column apply if

*The correction factor is defined as the ratio of the products of the sources, eye and cell spectral functions summed at suitable wavelength intervals:

$$F = \frac{R_1}{R_2} = \frac{\dfrac{\Sigma S_1 \cdot Y}{\Sigma S_1 \cdot C}}{\dfrac{\Sigma S_c \cdot Y}{\Sigma S_c \cdot C}}$$

Where, Y is relative eye response at wavelength λ
C is relative cell response at wavelength λ
S_1 is relative emission of source I at wavelength λ
S_c is relative emission of calibration source at wavelength λ

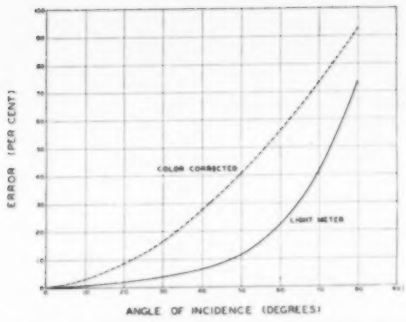


Figure 5. Chart illustrating errors in angular response for Light Meter and glass color-corrected cell of Fig. 4.

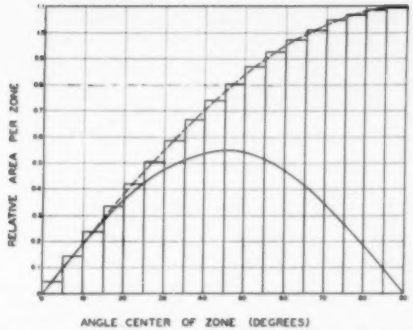


Figure 6. Chart of zonal constants of sphere, indicating relative areas contributing illumination to horizontal surface at various angles. Ordinate gives area for usual 10 degree zones (dotted) (divide by 2 for 5 degree zones indicated by steps). The solid curve is the product of zonal constant and the cosine of the angle of light incidence, hence is indicative of relative contribution to horizontal illumination of the various zones of a uniformly bright hemisphere.

the instrument was calibrated in the usual way under an incandescent source of 2700° K color temperature; while those of the second column correspond to calibration under an incandescent lamp at 2900° K. It also will be noted that the values have changed somewhat since the earlier study.[10] This is due to slight changes in the spectral characteristics of improved cells and lamps through the years.

Future changes in either cells or light sources would be expected to further modify any given correction factors. The situation is further complicated by the fact that each cell manufacturer utilizes a slightly different process which results in significantly different spectral response and hence a separate set of correction factors. Further, some manufacturers produce more than one variety of cell so that it may be necessary to know something of the history of a cell before it can be determined which table of corrections apply.

Hence, Table I is applicable only to the light meter of Fig. 1. As indicated by the table, this instrument may read 50 per cent low under green fluorescent lamps, while it reads more than twice the true value under light from blue fluorescent lamps.

One possible solution is to modify the cell response to match that of the Standard Observer. Since the cell response covers a wider spectral range than does the eye, it is quite possible to develop filters to subtract from the incident light just the proper proportion to reduce the cell sensitivity to match the relative eye response at each wavelength. However, when such a combination of blue and amber filter glass was designed, it was found that the overall filter transmission was only about ten per cent. To obtain an acceptable color correction, this filter reduced the cell output to a point where very sensitive meters were

Figure 7. Photograph of multi-cell color-corrected diffusing plate light meter.[10] (See References.)

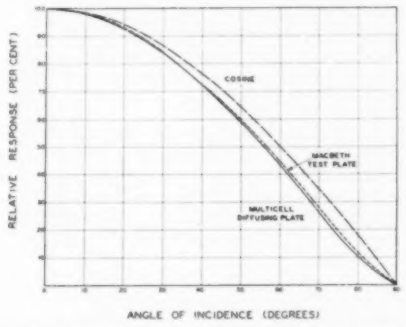


Figure 8. Chart of relative angular response of multi-cell color-corrected diffusing plate light meter and Macbeth test plate in comparison with theoretical cosine response.

required to allow readings at prevailing interior illumination levels. These more sensitive meters were more expensive and less rugged, taking the color-corrected light meter out of the category of a field instrument, although the use of color-corrected cells in the laboratory has become extensive.

Angular Response

Widespread use of linear sources intensified the need for another type of correction, that for the angle of incidence of light upon the cell. The familiar Lambert's Law states that the horizontal component of light intensity is the product of the beam intensity and the cosine of the angle of incidence, defined as the angle between the beam and the normal to the surface, Fig. 3:

$I_h = I_b \cos. \theta$. Where θ is the angle of incidence.

While this is true regardless of the nature of the source, the recent use of fluorescent lamps in continuous rows in very large rooms, *e.g.* aircraft and other factories, stores, etc. has focused attention on the fact that an appreciable proportion of the horizontal illumination at a given point may come at large angles, from lamps at considerable distances. Further, measurement of light at near-grazing angles is often of maximal importance, *e.g.* in interiors lighted by natural light from windows, and in the lighting of streets, ball parks, etc.

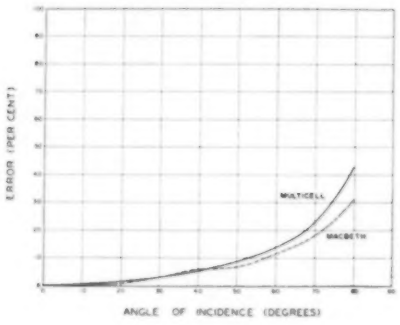


Figure 9. Chart illustrating errors in angular response for multi-cell color-corrected diffusing plate light meter and Macbeth test plate.

Figure 10. Diagrammatic sketches of light paths in (A) Bare cell, mounted; (B) Glass covered cell, light meter; (C) Glass color-corrected cell; (D) Multi-cell color-corrected diffusing plate light meter. Shielding of cell by housing indicated in (A). Surface reflection losses indicated for various types of instruments, (A), (B), (C), (D).

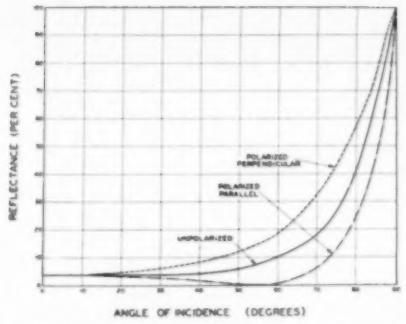


Figure 11. Chart showing relative reflectance of polarized and unpolarized light at various angles of incidence. (Refractive index of material = 1.490).

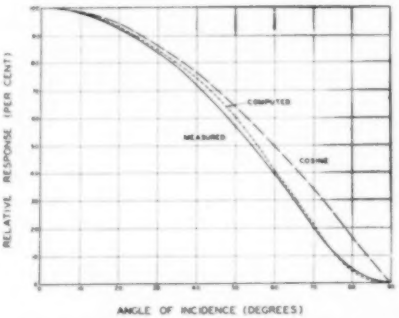


Figure 12. Chart indicating computed (dotted curve) and measured (solid curve) angular response for glass-covered cell (light meter).

It was established some time ago[10] that the standard light sensitive cell did not respond to light in accord with the Lambert cosine law. In fact, while the error is only a few per cent for light striking the cell within a narrow cone of 30°, the error may easily reach 40 per cent for the light entering at 70°, and about 75 per cent for that at 80°. Data for the angular response of the "light meter" and a standard cell, color corrected with glass filters, are given in Fig. 4. At the greater angles a small deviation from the theoretical cosine (dashed curve), represents a much larger

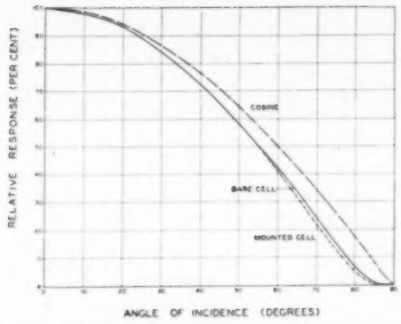


Figure 13. Chart showing angular response of an uncovered selenium cell before (solid curve) and after mounting (dotted curve) in comparison with theoretical cosine response (dashed curve).

error than the same apparent separation at the smaller angles. Hence, a second chart is presented, Fig. 5, to show the variation in per cent deviation or "error" from the theoretical.

"Error" is defined:

$$e = \frac{T - R}{T}$$

where T = Theoretical cosine value at angle θ
R = Actual relative response at angle θ

It is seen that in terms of angular response, cells color-corrected with the glass filters are more seriously in error than uncorrected cells, the error reaching about 75 per cent at 70° light incidence and over 90 per cent at 80°.

While it is true in many cases, that most of the light is incident nearly normal to the working surface, yet the trend is toward more uniform brightness patterns throughout the room. Hence, useful light at large angles of incidence is becoming more important. The areas contributing light flux to a horizontal plane increase rapidly at the large angles. This is the familiar "zonal constant" which is plotted on the basis of 10° zones in Fig. 6.[11]

Inspection indicates that for a uniformly bright interior, the cell error at 70-80° light incidence merits over ten times the weighting of the error at 0-10° incidence. On the other hand, for many situations, the light at grazing incidence may be relatively ineffective in producing horizontal candlepower due to the distance from the light source to the point of measurement. Street lighting is one example, wherein the light from angles greater than 60° or 70° produce relatively little horizontal illumination although very effective in producing pavement brightness.

Previously, steps have been taken to provide angular correction to match the cosine law, and the familiar Multi-Cell Color-Corrected Diffusing Plate instrument, Fig. 7, was developed[10] and has been widely used during recent years. However, in addition to the 90 per cent of light sacrificed in obtaining acceptable color correction, approximately 70 per cent of the remaining fraction is lost in order to obtain cosine correction equivalent to the long established Macbeth test plate, Figs. 8 and 9, leaving a sensitivity only three per cent of that of an uncorrected cell. Thus, even with the most sensitive meters practicable for field use, it was necessary to use several standard cells in parallel to get sufficient output to measure even the higher intensities encountered. The lowest range of the multi-cell unit is 50 footcandles, full scale. In spite of the limitations of complexity, delicate meters, and high

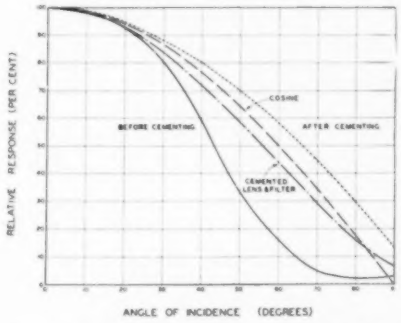


Figure 14. Chart showing angular response of a cell covered with a thick lens (solid curve); with the lens cemented to the cell (dotted curve); and then with a color-correcting filter laminated between the lens and cell (dot-dash curve).

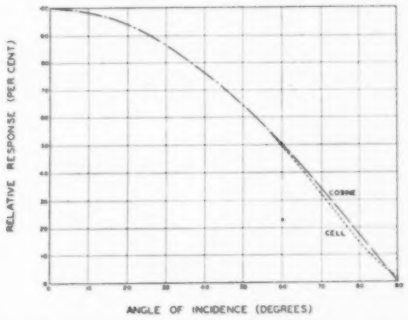


Figure 15. Curve of angular response of thin flat lens (design S-1) cemented to standard rectangular photovoltaic cell, average of crosswise and lengthwise planes (dotted curve) compared with theoretical cosine (dashed curve).

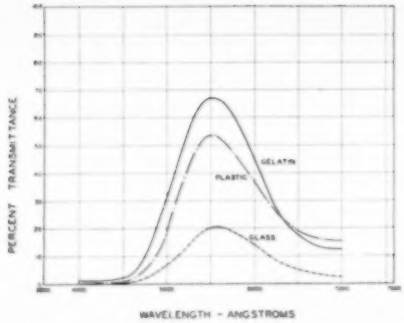


Figure 16. Spectral transmission data for color-correcting filters, glass (dotted curve); plastic (dot-dash curve); and gelatin (solid curve).

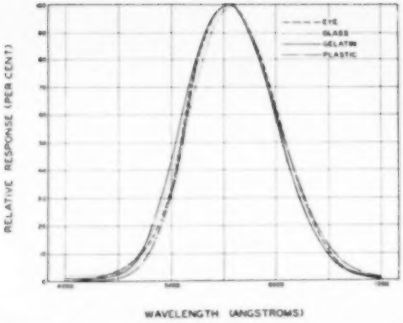


Figure 17. Computed spectral response for average selenium cell of Fig. 2 covered with filters, glass (dotted curve); plastic (dot-dash curve); and gelatin (solid curve); compared with 1931 I.C.I. average human eye (dashed curve).

cost, the need and demand for this instrument has grown steadily.

Apparently several types of light-intensity-measuring instruments are needed at the present time. While in each case it may be desirable to attain the maximum in response, stability and compactness with the minimum of cost, the optical requirements seem to differ somewhat for the various types:

1. Perhaps the most urgently needed and the most widely applicable instrument is a pocket light meter corrected for color and angle of light incidence and with a range of about 0 to 100 footcandles for everyday field use, regardless of the color of the source or the geometry of the installation.

2. There seems to be a steady demand for a precision, multi-range, color-and-angle-corrected instrument with a low range of about 0 to 10 footcandles for laboratory and field studies.

3. For some rather special but important applications, *e.g.* street lighting, there is a requirement for an instrument of maximum response, perhaps 1.0 footcandle full scale and very good cosine correction, but where color correction could be computed with the appropriate factors.

4. There is a need, particularly in fixed laboratory setups, for an efficient color-corrected cell, but where angular response is not a factor.

5. There remains a field for simple cells without correction.

TABLE II—Relative Response of Various Cells

Type	Construction	Angle of Light Incidence 0°	40°	90°
Bare Cell		100	73	7.0
Standard Light Meter	Glass covered cell	92	66	4.1
Color-Corrected Cell	Amber and blue filters	9	5.0	0.1
Multi-cell Diffusing Plate	Diffusing plastic, amber and blue filters over cell	3	2.2	0.3

Recently attempts have been made to appraise the optical characteristics of the available cells and light meters. Fig. 10 may serve to indicate the losses which occur by surface reflections, by shielding and by diffusion in the various types of uncorrected and corrected cells discussed above. Table II presents the readings obtained with a bare cell, covered with clear glass, covered with blue and amber glass filter combination and finally covered with both the filters and the diffusing plate. The illumination was held at the same intensity throughout the test and the light entered the cell perpendicular to the surface. Values for the other angles are computed from the curves of Figs. 4 and 8.

It is well known that surface reflections increase with the angle of incidence of the light so that most surfaces approach "mirrors" at near-grazing angles. Theory and experiment have established the factors which affect the reflection of light incident at a boundary surface between two media of different indices of refraction. The reflecting power, or ratio of emergent to incident intensity, is found to depend upon the state of polarization of the light, the angle of incidence and the indices of refraction of the two media involved. The Fresnel equations[12] for reflecting power are:

$$R_1 = \frac{I_e}{I_o} = \frac{\sin^2 (i-r)}{\sin^2 (i+r)}$$

for light polarized perpendicular to plane of incidence where: i is angle of incidence
r is angle of refraction

and,
$$R = \frac{I_e}{I_o} = \frac{\tan^2 (i-r)}{\tan^2 (i+r)}$$

For light polarized parallel to plane of incidence.

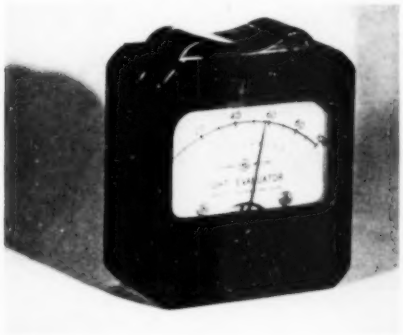
Thus for unpolarized light, which may be considered as one-half polarized in each plane:

$$R_u = \frac{I_e}{I_o} = \frac{1}{2}\frac{\sin^2 (i-r)}{\sin^2 (i+r)} + \frac{1}{2}\frac{\tan^2 (i-r)}{\tan^2 (i+r)}$$

Fig. 11 illustrates the variation of reflecting power with the angle of incidence for polarized and unpolarized light at the boundary surface of air and a glass, plastic, or other material of index of refraction of 1.490. For light at normal incidence, $n = \frac{i}{r}$; hence this reduces Snell's law, $R = \frac{I}{I_o} = \frac{(n-1)^2}{(n+1)^2}$, and solving, one finds the familiar four per cent first-surface reflection loss. Thus, the two additional surfaces of the cover glass are responsible for the eight per cent loss, giving the 92 per cent, "perpendicular optical efficiency" for the standard glass covered cell seen in Table II. Fig. 12 gives a computed response curve for the standard glass-covered cell compared with a measured curve. In addition to the reflection losses caused by the cover glass at large angles of light incidence, the cell housing shields a portion of the cell and further lowers the overall response. The effect is not significant at angles under about 60° but becomes increasingly a factor at greater angles.

With light incident at greater angles, it is noted from Fig. 11 that the reflection loss increases, being about 10 per cent per surface at 60° and about 40 per cent at 80°. It became apparent that the greater the number of surfaces, the greater would be the reflection loss and the cosine error at large angles. The thought then occurred that the converse must hold, *i.e.* the elimination of surfaces would improve the cosine response, and this has been verified experimentally.

Figure 18. Photograph of new pocket size light meter corrected for color and angle of light incidence.



Applying these considerations, cells were made up with various clear and diffusing glass and plastic covers laminated to the cell with cements of suitable refractive index to reduce reflections at the "interior" surfaces and to bring the entrance pupil up at least to the level of the housing. Marked improvement in the cosine response was immediately noted. However, there were several complicating factors which had to be explored before a design could be adopted. Theory and tests showed that the reflectance of the bare cell varies with angle of light incidence and hence the cell itself does not follow the cosine law, Fig. 13, although it is slightly superior to the glass-covered cells, Fig. 4. Like other boundary surfaces, the air-cell interface has a reflection characteristic similar to that of Fig. 11. Further, as noted in Table II, the use of diffusing materials to increase the relative response at low angles, markedly reduced the overall response due to the light reflected and absorbed.

Therefore, lenses were computed to compensate for the cells' failure to follow the cosine law. Being clear, these had very low reflectance and absorption losses and the interior surfaces were "removed" optically by cementing. Fig. 14 indicates the effectiveness of reducing these surface reflections; the lower curve was taken with one of the first lens designs placed over the cell; the upper curve is for the same lens cemented to the same cell. Obviously this laminated cell was over-corrected at all angles of light incidence, so that additional designs were studied until the result given in Fig. 15 was obtained with a thin lens. Another difficulty arose from the fact that the usual light cell is asymmetric in shape. Hence to form a lens surface of continuous contour for ease of maintenance, manufacture etc., it became necessary to overcompensate slightly

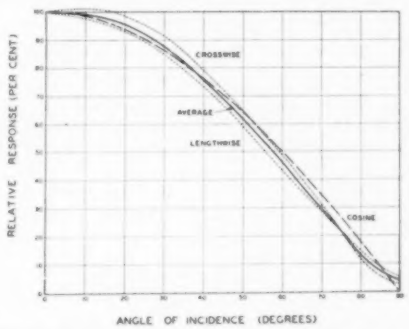


Figure 19. Chart of angular response of new laminated cell, color-and-cosine-corrected light meter. Crosswise and lengthwise planes are given by dotted curves and the average as the solid curve.

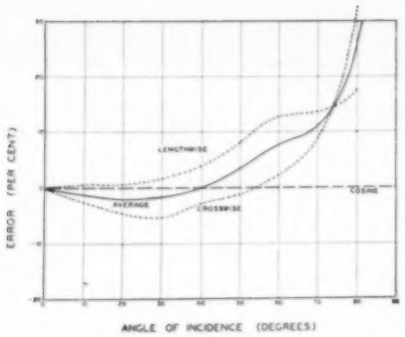


Figure 20. Chart showing error in angular response for new light meter of Figs. 18 and 19.

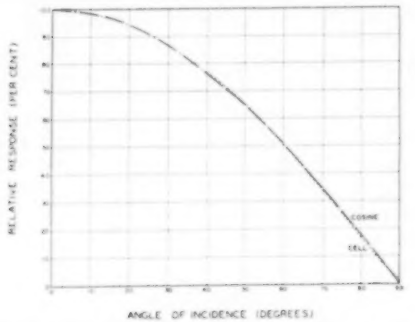


Figure 21. Chart of angular response of a thin flat lens cemented to a new 4" circular selenium cell (dotted curve) compared with theoretical cosine response (dashed curve).

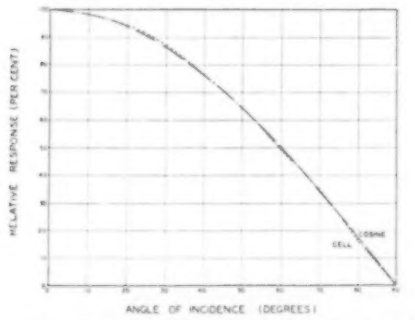


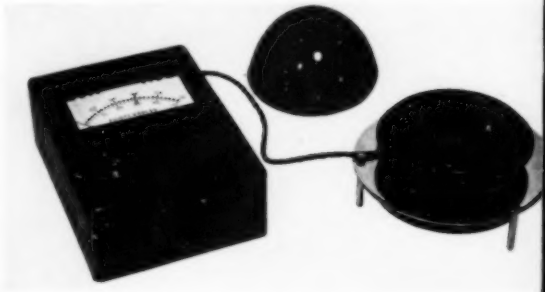
Figure 22. Angular response of laminated 4" cell of Fig. 21, when covered with plastic hemispherical filter (dotted curve) compared to theoretical cosine (dashed curve). A shallow louver removes the stray light at 90°.

in one plane and undercompensate in the other for the best average response. The small differences will then approximately cancel out when diffused light or sources from many directions are measured. If maximum precision is required in measuring the illumination for a small source, the cell may be rotated 90° and the two readings averaged, although in either plane the new design is superior to previous instruments. Or, one could measure the angle of light incidence and apply the correction factor from the given curve. At this point, it was noted that cosine response had been achieved at no loss in cell response; the laminated cell having slightly greater sensitivity than the standard cell.

However, the ultimate objective was the creation of a color-and-cosine-corrected cell, so that a filter had to be incorporated into the system. Although the surface reflection losses of the filter could be reduced by cementing, the transmission of the filter varies as its effective thickness varies with the angle of incidence. Hence, it again became necessary to compensate by the lens contour. Much thicker lenses were found necessary to correct for the filter loss at wide angles. The asymmetric shape of the cell again increased the difficulty in obtaining good angular response in the two planes with a continuous lens surface.

Glass, plastic and gelatin filters have been investigated for this application. The gelatin and plastic types were selected as the most reproducible and with the highest transmission for a given degree of color correction, Fig. 16. Comparisons of the relative response of the average eye and of average cells covered with these filters and with the prior blue and amber glasses is given in Fig. 17. It is noted that the transmissions of the gelatin and plastic are approximately three to four times that of the glass filters. This provides substantial gain in cell sensitivity, which has been needed for many applications. Critical comparison of the spectral transmissions of the three types of filters indicates that all are satisfactory for ordinary continuous light sources, although one may be slightly superior

Figure 23. Photograph of the low-range precision light meter equipped with automatic leveling gimbal mount for such applications as street lighting. Sensitivity ranges of 0 to 1 and 0 to 5 footcandles are obtained with the 4" laminated cell of Fig. 21.



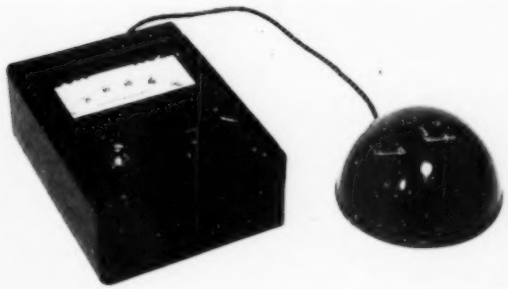
for mercury line radiation and another for sodium line radiation when calibrated with filament. Both gelatin and glass filters have been exposed to several hundred thousand footcandle hours of natural daylight at high intensities with measurable but not serious change in transmission characteristics. Similar studies are underway with the plastic material.

New Pocket Light Meter

Thus, during the course of two years, several hundred variations of the laminated cell technique have been studied. It is believed that the first objective indicated above, *i.e.* for a pocket light meter corrected for color and angle of light incidence, has been achieved with the design shown in Fig. 18. The spectral sensitivity of this laminated cell design is given by the curve for gelatin in Fig. 17, and the angular response in Figs. 19 and 20. The dotted lines are for lengthwise and crosswise planes, and the solid line is the average of both planes. Although the meter reads several per cent high at small angles and several per cent low at large angles, under most conditions these errors are well within that of meter accuracy and calibration. Further, it is noted that these errors tend to cancel when light is incident from many angles.

The cosine correction is attained without additional optical losses, hence only the filter transmission lowers the cell response, and the "perpendicular optical efficiency" is found to be 42 per cent or about 14 times that previously achieved with a color-and-cosine-corrected cell, Table II. Further, the color-correction is at least as good and the cosine-correction substantially better than before available. Hence improved instruments corresponding to objectives 2 and 3 became practicable by connecting the proper cosine-corrected or color-and-cosine-corrected laminated cells in parallel, and development instruments of these characteristics have been made. The marked increase in light transmission of the gelatin over the glass filters, approximately 400 per cent, substantially meets objective 4.

Figure 24. Photograph of the new multi-range precision light meter which utilizes the laminated 4" cell, Fig. 21, and color-correcting hemispherical filter, Figs. 17 and 22.



Low-Range Precision Light Meter

Nevertheless, it was felt that the potentialities of cell lamination were such as to justify the development of a large symmetrical cell which would allow more perfect cosine correction and greater sensitivity for a lower range instrument. Work was begun on a two-inch circular cell and preliminary cosine and color cosine lenses were made.

At this juncture, consultation with street lighting specialists indicated the desirability of an instrument with a full scale reading of one footcandle or less, so that even the minimum values as indicated by the American Standard Practice for Street and Highway Lighting[13] could be measured. Preliminary estimates indicated a cell of four-inch diameter would be required and this development was undertaken, resulting in a combination with nearly perfect angular response as indicated in Fig. 21. When a hemispherical filter is placed over this design, little or no change in angular response is noted, Fig. 22. The erroneous reading of about one per cent caused by stray light at 90° is removed by a very shallow louver where such error is significant.

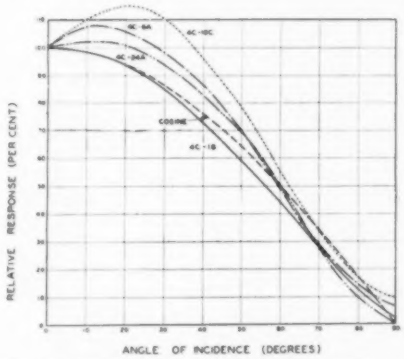


Figure 25. Angular response of a typical group of 4" circular cells laminated with thin gelatin filters and lenses between 0.25" and 1.75" in thickness. Dashed curve represents theoretical cosine response.

For the street lighting application, the laminated cell construction of Fig. 21 is mounted in an automatically leveling gimbal and used with a sensitive microammeter, Fig. 23. While 0.50 foot-

candle full scale deflection has been obtained with this cell and a standard microammeter, experience indicated a more rugged meter, giving 1.00 footcandle full scale indication, to be better suited for field work. An additional scale of 0 to 5 footcandles is provided by means of a shunt. Choice of sensitivity ranges is made by the toggle switch and the momentary contact switch is provided so that the meter will not be connected to the cell when exposed to high intensities. The calibration of this "low range precision light meter" is made without any color filter, but a "snap-on" hemispherical filter is provided and the filter factor is marked on it so that scale readings may be converted to footcandle values. For many applications, *e.g.* street lighting, the correction factors of Table II are convenient to use when sources other than incandescent are encountered. The filter should be used when mixtures of various sources are encountered.

Multi-Range Precision Light Meter

The laminated cell of Fig. 21 is also used in a "multi-range precision light meter," Fig. 24. In this case, the hemispherical filter is fastened to the cell mounting and the meter is calibrated to 10, 100 and 1000 footcandle full scale values with the filter in place. A still more rugged microammeter is provided since maximum sensitivity is not required. No gimbal is provided although the cell mounting is interchangeable with the low-range design and could be used if desired.

A number of lens and filter laminations also were made and studied. Some of the better ones are given in Fig. 25, the color response being as given in Fig. 17. These lenses were from 0.25" to 1.75" thick and are not as close as desired to cosine response, although the errors in some cases may be less than the prior art and are compensating in diffuse or multi-source measurements.

It is anticipated that the sealed construction of laminated cells may result in more stability and greater resistance to handling, weathering and corrosion. However, life studies have not proceeded to where this is definitely established. Except for a few rather special applications, the matter of cell life is only of academic interest. When used in the normal way, the instrument life is very long and is usually determined by factors other than cell life.

Summary

Lamination of simple lenses to the surface of photovoltaic cells has been shown to greatly improve the angular response of such cells. Combined with new filter materials of greater light transmission, more accurate light measuring instruments have been developed. Instruments utilizing the laminated cell construction are specifically described, including a new pocket light meter, corrected for color and angle of light incidence; a low-range precision light meter; and a multi-range precision light meter.

Acknowledgments

The development of these instruments, involving as it did designs of several hundred laminated cells, has drawn upon the skills of a great many individuals. The author is particularly indebted to his wife, Mrs. Elizabeth S. Buck, for her assistance and tolerance in connection with making of the cell laminations, and to Mr. E. P. Meko and his associates in the Engineering Division, who made the bulk of the angular response measurements. Messrs. G. P. Kerr, Jr. and E. T. Leppelmeier of the General Electric Lighting Research Laboratory made the spectral transmission measurements on the various types of filters. The new large-size cells were developed through the efforts of Messrs. A. J. Stimson, J. J. FitzPatrick, W. E. Briggs and J. F. Weary of the Lynn Instrument Works of the General Electric Company. Dr. E. M. Lowry, Research Laboratory, Eastman Kodak Co., developed the gelatin filters and provided ultraviolet transmission data for this material. Last, but by no means least, appreciation is expressed to Mr. C. L. Dows, Engineering Division, whose friendly interest guided the development for a period of over two years.

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TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Review of Council Meeting Held in Chicago

Scheduling the April meeting of Council for Chicago on the weekend following the recent International Lighting Exposition enabled large numbers of visiting chairmen as well as Council members to attend. Other members may find of interest a resume of the more pertinent actions taken.

The meeting was attended by: Lee E. Tayler, President; G. K. Hardacre, R. W. Staud, Past-Presidents; C. H. Goddard, Walter Sturrock, Vice-Presidents; E. M. Strong, Treasurer; Myrtle Fahsbender, Carter Lewis, Hoyt P. Steele, M. N. Waterman, Directors; G. W. Beals, R. L. Biesele, Jr., Joe B. Browder, L. M. Endres proxy for Harry Grattan, Jr., W. V. C. Foulks proxy for Duncan M. Jones, Edwin H. Laugh, H. H. Magsdick proxy for T. H. Shepherd, William A. Stannard, Regional Vice-Presidents; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director, G. Ross Henninger, Director of Publications; C. E. Ellis, Advertising Manager. Also present were C. L. Amick, R. G. Beals, R. R. Brady, R. J. Deifenthaler, R. R. Enghouser, J. W. Griffith, J. M. Guillory, S. B. Hibben, J. M. Hickerson, P. H. Hildebrand, E. C. Huerkamp, J. O. Kvalsten, R. R. Lusk, C. O. Martin, L. B. Paist, R. C. Putnam, J. S. Schuchert, R. G. Slauer, J. M. Stedman, A. F. Wakefield.

Membership Totals

Action was taken on the report submitted by R. C. Kinney, Chairman of the Membership Committee and resulted in the election of 15 members, 138 Associate Members, and 37 Students. Current Membership totals were reported as shown in the following tabulation:

September 30, 1948		April 2, 1949
6,516	Total membership	7,068
21	Members Emeritus	25*
45	Fellows	43
1,406	Members	1,498
4,908	Associate Members	5,265
136	Student Members	237

*Includes 5 Fellows of the Society.

Committee Appointments

President Tayler submitted to Council a number of new committee appointments. Favorable action assigned the following new committees and additional personnel to the Society's committee structure:

Advisory Committee on Committee Personnel—C. H. Goddard, Chairman; C. L. Crouch, G. K. Hardacre, A. D. Hinckley, R. W. Staud.

Aviation Lighting—Editorial Board of Sub-Committee on Compendium for Aviation Lighting: F. C. Breckenridge, Chairman; H. R. Blackwell, C. L. Crouch, W. E. K. Middleton, J. M. Waldram.

Industrial Lighting—Harry Keane.

Lighting of Central Station Properties—R. W. Corwin, W. S. Mowry.

Light Control and Equipment Design—B. S. Benson, Jr., to replace J. H. Waterbury.

Lighting Study Projects in Educational Institutions—Committee on Brightness Conditions in Educational Visual Environments: C. N. Laupp, Chairman; Willard Allphin, J. M. Chorlton, W. E. Folsom, L. V. James, W. H. Kahler, Phelps Meaker, L. B. Paist, J. S. Walsh.

Street and Highway Lighting—R. P. Brotsman.

Sub-Committee on Pavement Surfaces: A. A. Anderson, Fred W. Fisch, Bernard E. Gray, G. A. Trosper, Wayne N. Volk.

Tellers—Virginia Skinner, Chairman; W. A. Hayman, John MacDougall, Robert A. Most, Priscilla Presbrey.

President's Highway Safety Conference—Engineering Committee—R. M. Zabel to replace Stuart R. Williams.

Committee on Organized Public Support: Lee E. Tayler.

Publication Policy

Based on Committee agreements reached at a special meeting of the Publications Committee held jointly with the National Technical Conference Committee and C. L. Crouch, Technical Director, E. C. Huerkamp, Chairman of Publications Committee, presented to Council his committee's recommendations with regard to editorial policy for Illuminating Engineering. Council voted to accept as a guide to publication policy the statements recommended by the Publications Committee. The committee had recommended that:

(1) The editorial content of the journal follow the outline approved by Council in April, 1948, in the report of the Task Committee on Editing the Society's New Journal, as follows:

a. Current lighting installations and developments in materials and applications, presented in easily readable form to appeal to members and subscribers whose interest is not primarily technical. This includes presenting lighting data sheet material.
b. Abstracts or summaries of technical papers subsequently to be available in full.
c. Significant and timely items from related sciences and arts, of both domestic and foreign origin.
d. Basic technical information and advanced thinking for professional development in the field of illuminating engineering.
e. National I.E.S. policies, programs, and activities, including committees—the Society's voice for interpretation, leadership.
f. Editorials.
g. News of Regional and Local activities and personalities.
h. People significantly in the news.
i. Expression of membership opinion through letters. Question and answer service.
j. Transactions material—complete papers with discussion.

(2) That in order to meet these objectives it may not be possible to publish Technical Committee reports in full in Illuminating Engineering within the current budget limitations.

(3) Further, that the membership will be best served if some of the reports are first published as digests.

(4) That the Publications Committee feels technical reports are of value to the membership and deserve all possible space in Illuminating Engineering; that they should be printed in full in some form.

Mr. Huerkamp also reported that the committee is preparing a guide recommending on policy and procedure relative to the presentation of subject matter in Technical Committee reports.

In discussing these statements, Mr. Huerkamp expressed the belief that the new Journal content is following closely the outline of contents approved in the April 1948 report.

Discussion prior to final action emphasized that the complete Transactions of the Society will, as always, be published and that the Publications Committee has under study means for making the complete Transactions available to the membership in one or more forms. During the current year all Transactions material will be included in the regular issues of ILLUMINATING ENGINEERING, the committee reported. Discussion also established that any future digests of Technical Committee Reports would be made with the cooperation and approval of the sponsoring committee, as is proposed in the analogous case of digests of Conference Papers.

NEW SUSTAINING MEMBER

Favorable action of Council on the report of the Sustaining Membership Committee, submitted by George J. Taylor, resulted in the election as Sustaining Member of:

British Columbia Electric Railway Co., Ltd.
570 Dunsmuir St.
Vancouver, B. C., Canada
Official Representative—H. N. Walters

WARD HARRISON 1949 MEDALIST

Acting on recommendation of the I.E.S. Medal Award (A. F. Wakefield, Chairman), Council approved that Dr. Ward Harrison receive the 1949 I.E.S. Gold Medal Award. Details on Dr. Harrison's distinguished career are published elsewhere in the Telecast section of this issue.

NEW MARITIME CHAPTER ESTABLISHED

Another Chapter of I.E.S. was established by action of Council, the latest being the Maritime Chapter, with headquarters at St. John, New Brunswick, Canada. This brings to four the number of Sections and Chapters now active in Canada, with indications that still another will be formed soon in the Quebec area. The new Maritime Chapter includes all of the Provinces of New Brunswick, Nova Scotia and Prince Edward Island.

NEW STUDENT BRANCH

Walter Sturrock, Chairman of the Local Activities Committee, reported the interest of a student group at Mississippi State College in establishing an I.E.S. Student Branch there. Acting on his recommendation, Council confirmed the appointment of Robert J. Wiseman as local representative at Mississippi State College and approved a Charter for this new Student Branch.

LOCAL ACTIVITIES CONFERENCE JUNE 9

Mr. Sturrock further referred to a forthcoming Conference on Local Activities which has been called for June 9 in New York City. He indicated that incoming Section and Chapter officers had found attendance at similar conferences most beneficial to the planning and operation of local affairs.

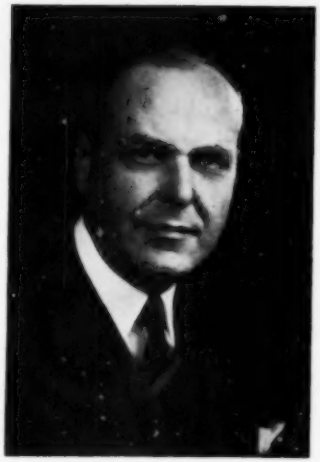
CONFERENCE PREPRINTS TO BE $1.00 PER SET

On the recommendation of the National Technical Conference Committee, Council voted to make available to each member attending the French Lick Conference, sets of preprints of the Conference papers at $1.00 per set. R. F. Hartenstein, Chairman of the Conference Committee, stated that these receipts, together with the budgeted publication costs, would be transferred to the Publications Committee budget to help offset the expense of preprinting papers for the Conference. General discussion preceding this action indicated that copies of the papers would be available in advance to permit the preparation of discussions. It was also indicated that the provision of sets of preprints or individual copies for members not attending the Conference would be arranged by the Publications Committee.

Ward Harrison 1949 Medalist

The I.E.S. Gold Medal and Award Certificate, highest honor in illumination, has this year been awarded to Dr. Ward Harrison, retired Director of the Engineering Division of General Electric Lamp Department. Dr. Harrison's election for the award was unanimously approved by Council at its April 2 meeting in Chicago, on recommendation of the I.E.S. Medal Award Committee. The I.E.S. Medal, the Society's top honor, is awarded "for meritorious achievement conspicuously furthering the profession, art, or knowledge of illuminating engineering."

Few people in the profession have had more influence than Dr. Harrison in the development of the art and knowledge of illuminating engineering. For almost 20 years, he was Director in charge of the largest illuminating engineering organization in the world,



Dr. Ward Harrison

and was a pioneer in the formation of the Lighting Institute at Nela Park.

In almost all phases of illumination development — Lighting Technology — Design of Lighting Equipment—Specification and Certification Programs——Lighting Education—Lighting Practice—Dr. Harrison has made many valuable contributions.

In Lighting Technology, Dr. Harrison established, in collaboration with E. A. Anderson, coefficients of utilization for a comprehensive range of lighting equipments and room descriptions, and devised a radically new room-index method of illumination calculations, now and for many years past almost universally employed in this country and abroad. In this field also, he created unique demonstrations of the factors determining comfort as affected by the lighting system, and proposed and implemented a system of numerical glare ratings. For the first time it was made feasible to predetermine fairly closely the degree of comfort which would be afforded by a proposed lighting installation.

The RLM Standard industrial reflector—used throughout the world and a basic design with many manufacturers, was designed by Dr. Harrison. Numerous other designs in lighting equipment widely employed in many countries were also original designs of Dr. Harrison's invention. Some of these include the glassteel diffuser; the first clear-top enclosed semi-indirect luminaire; the first street luminaire with prismatic dome refractor. Dr. Harrison was the first to apply perforated metal to luminaires for shielding sources, redirecting light, and adding new appearance interest, and

through the years leading equipment manufacturers have sought his counsel in new developments and improvements in lighting equipment.

An educator of note in the lighting field, Dr. Harrison has for a number of years been a special lecturer on illuminating engineering at the Case Institute of Technology, Cleveland, Ohio, and is the author of two text books on the subject, as well as numerous papers in the *I.E.S. Transactions* and other publications.

Dr. Harrison's contributions to the Illuminating Engineering Society, of which he is a Fellow, have been of equally major importance. In addition to his term as President (1922-23) he has served the Society as chairman and member of innumerable committees, as well as Official Representative to the U. S. National Committee of I.C.E., Sectional Committee of A.E.S.C., and as Board Member of the Pittsburgh and Cleveland Sections of I.E.S.

The award of the I.E.S. Gold Medal is the latest of many honors conferred on Dr. Harrison. In 1940 he received the honorary degree of Doctor of Illuminating Engineering from the Case School of Applied Science, the first such degree granted in America. The eminence he has attained in his profession is perhaps unsurpassed by any member of the profession. An instance indicative of his world-wide prestige is the invitation last summer to deliver the principal address at the 1948 Convention of the British Illuminating Engineering Society, an honor reserved for the most distinguished of illuminating engineers.

June IE to Feature Trends Indicated at I.L.E.

A special section of the June issue of ILLUMINATING ENGINEERING is being prepared, to cover in a very comprehensive manner, an analysis of the trends in lighting design, application and practice as reflected by the exhibits and other activities of the enormously successful Third International Lighting Exposition. Pictures and pertinent information on the top 24 Merit Award winning installations will be a special feature.

As already well covered by the May issues of the trade press, the Third International Lighting Exposition, held in Chicago March 29 to April 1, afforded thousands of people of the lighting industry the opportunity to study first hand the newest developments in application technique. On every day of the four-day exposition, the large Exhibition Hall was open for inspection from nine in the morning to six at night—with all evening as well on Thursday. A total of 7000 men and women visited the 77 exhibits on display.

Theme of the Exposition and Conference was "New Light on Planned Lighting." The concept of planned lighting, first introduced three years ago by the Industrial and Commercial Lighting Equipment Section of N.E.M.A., sponsors of the Exposition, is now accepted industry-wide. The numerous new trends displayed this year well exemplified the Show's theme.

The Merit Award Competition, sponsored as a feature of the Exposition, resulted in 220 winners of the Gold Seal, Merit with Distinction (a new group created this year) and Merit Awards for original and outstanding lighting installations. All of the winning entries, for the first time, were displayed in a Gallery of Merit Awards throughout the period of the Show. Presentation of the 14 Gold Seal $100 Awards were made at the opening session of the Conference by R. D. Bradley, Chairman of the Merit Award Competition Committee and Carl Zersen, Chairman of the Board of Judges. The 14 top winners, together with the ten top Merit with Distinction and Merit Awards will be presented in June ILLUUMINATING ENGINEERING, with other details of the Exposition.

Announced winnecs of the Gold Seal $100 awards were: in the utility lighting and power representative classification — Eugene M. Fahey and J. A. Heffernan, Public Service Electric & Gas Co., Newark, N. J. for a joint entry on an electrician's shop; Walter E. Turnbull, Public Service Electric & Gas Co., Plainfield, N. J., joint with North Plainfield Board of Education, owners and users, Plainfield, N. J., for classroom lighting; Burdette E. Sanderson, Public Service Co. of Northern Illinois, Joliet, Illinois, for a bank.

In the electrical contractors classification, the winners are John O. Kvalsten, Kvalsten Electric Co., Inc., Minneapolis, Minn., with Donald Greene, Larsen & McLaren, architects, and B. R. Bunn, Westinghouse Electrical Supply Co., for a bank; Herman G. Johnson, Northern Power Co., Minneapolis, with John Christianson Electric Co., contractors, for a floral shop; William H. Rorabough, Hudson Morgan Co., Inc., Lynchburg, Va., for a maintenance shop.

In the architects and consulting engineer classification, the winners were J. L. Phillips, Birmingham, Ala., for a bank; Ernest C. Hinck, Jr., Montclair, N. J., for an office; Paul E. Keys, Duquesne Light Co., Pittsburgh, Pa., with Hyman Rosenberg, architect.

In the owners and users of industrial and commercial lighting, the win-

GOLD SEAL AWARD Winners, Third International Lighting Exposition. Reading from left to right: Front row—Herman G. Johnson, B. R. Bunn, Donald Greene, John O. Kvalsten. Second row—J. A. Heffernan, R. E. Hause, G. Chittenden, R. Bruce Thompson, Eugene M. Fahey, Walter S. Turnbull. Third row—Paul E. Keys, J. L. Phillips, C. E. Oswald, H. W. Horn, William M. Rorabough, F. W. Martin, B. E. Sanderson. Gold Seal Award winners not shown in the photograph are John Christianson, E. C. Hinck, Jr., Hymen Rosenberg, Robert S. Hoffman, George Seiter, and representative for the North Plainfield, N. J., Board of Education.

ning installations were Robert S. Hoffman, Perfection Stove Co., Cleveland, Ohio with G. Chittenden, George S. Rider Co., architects, for press work and steel storage lighting; H. W. Horn and C. E. Oswald, Department of Electrical Engineering, University of Illinois, Urbana, Ill., for an electrical engineering machinery laboratory; R. E. Hauss, Cincinnati Union Terminal, Cincinnati, Ohio, with George H. Seiter, Cincinnati Gas & Electric Co., for lighting of coach yard maintenance (railroad).

In the wholesalers lighting specialists and commercial lighting, the winners were R. Bruce Thompson, General Electric Supply Corp., Buffalo, N. Y. for a bank; F. W. Martin, Graybar Electric Co., Chicago, Ill., also for a bank.

Student Members Available After June Graduation

A number of the Society's Student Members will be interested in commercial connections after June graduation, especially where their student work in illumination will be the most valuable. Most of these Student Members have specialized in lighting, some at schools having an Illumination Option.

Members interested in contacting graduating I.E.S. Student Members for possible employment may get in touch with the following schools:

Case Institute of Technology
Cleveland, Ohio, Prof. R. C. Putnam

Cornell University
Ithaca, N. Y., Prof C. L. Cottrell

Mississippi State College
Starkville, Miss., Prof. R. S. Wiseman

Massachusetts Institute of Technology
Cambridge, Mass., Prof. Parry Moon

Penn State
State College, Pa., Prof. D. L. Markle

Southern Methodist University
Dallas, Texas, Prof. R. L. Biesele

Stanford University
Stanford, Calif., Prof. L. H. Brown

University of British Columbia
Vancouver, B. C., Canada, Prof. S. Morgan

University of Cincinnati
Cincinnati, Ohio, Prof. R. J. Dickason

University of Dayton
Dayton, Ohio, Prof. A. J. Holian

University of Illinois
Urbana, Ill., Prof. J. O. Kraehenbuehl

University of Michigan
Ann Arbor, Mich., Prof. H. S. Bull

University of Toronto
Toronto, Ont., Canada,
Prof. E. L. Dodington

University of Wisconsin
Madison, Wis., Prof. L. C. Larson

Pacific Northwest Conference Presents Exceptional Program

I.E.S. members in our country's farthest corner conducted a two-day Regional Conference recently that could well draw the admiration of any other corner, far *or* near. Its delegates were presented with a program of nationally recognized authorities in a series of very valuable symposiums on various phases of lighting. Every angle of conference planning was thoroughly organized months in advance for the smooth operation of every phase—from technical sessions to field trips to entertainment of the visiting ladies.

Host Section for the Conference was the Oregon Section and participating chapters included as well, Puget Sound, Inland Empire and British Columbia. The Conference, the third such annual meeting in the Pacific Northwest, was held at the Hotel Multnomah, Portland, Oregon, March 10 and 11, 1949. Guest of honor was I.E.S. President Lee E. Tayler, who addressed the gathering at the opening session.

Some 290 people attended this conference—the majority for every session. The technical program, as mentioned, was made up of special symposiums, for which separate registration was permitted. In addition to the full-conference delegates, many people came from a number of states to attend the symposium of special interest to them.

Technical Program

The four symposiums presented at the technical program of the Pacific Northwest Regional Conference each occupied half a day. The sessions included:

Lamp Symposium
Thursday Morning, March 10
Session Chairman—R. E. Lange

Opening Remarks—"The Scope and Aims of the I.E.S.," by Lee E. Tayler, National President of the Illuminating Engineering Society.

"New Developments in Fluorescent Lamps," by D. P. Caverly, Sylvania Electric Products Inc., New York, N. Y. (Discussion leader P. A. Donnelly.)

"Recent Developments in Incandescent Lamps," by Charles Long, Westinghouse Lamp Div., Los Angeles, Calif. (Discussion leader, Elmer Smith.)

Joint Luncheon Meeting, Electric Club and I.E.S. Conference delegates.

School Lighting Symposium
Thursday Afternoon, March 10
Session Chairman—A. E. Simpson

"Light for the Growing Child," by Dr. D. B. Harmon, Austin, Texas. (Discussion leader, Mike Henkel.)

"Optometrist's Viewpoint on Lighting," by Dr. A. E. Kidd, Vancouver, B. C. (Discussion leader, Dr. Richard Feinberg.)

"Lighting in New and Remodelled School Structures," by Beverly Travis, Consultant, Seattle, Washington. (Discussion leader, William Creech.)

A BROKEN foot sustained during the Pacific Northwest Regional Conference put E. A. Simpson, Chairman, British Columbia Chapter, in a wheelchair, but did not keep him from a single session. Pushing his chair is I.E.S. Pres. Lee E. Tayler, and shown with him are some of the 29 Conference delegates from Canada.

"Troffer Lighting at Coulee Dam School," by David Mozes, General Electric Supply Co., and T. R. Anderson, USBR, Spokane, Washington. (Discussion leader, Blair Plowman.)

Commercial Lighting Symposium
Friday Morning, March 11
Session Chairman—David Mozes

"Louverall Design," by G. B. Buck II, General Electric Co., Nela Park, Cleveland, Ohio. (Discussion leader, Henry Huber.)

"Modern Trends in Store Lighting," by A. M. Hurly, Canadian General Electric Co., Vancouver, B. C. (Discussion leader, B. T. Heinz.)

"Pros and Cons of Lighting Systems," by D. P. Caverly, Sylvania Electric Products Inc., New York, N. Y. (Discussion leader, Edward Cofferro.)

Light Source Symposium
Friday Afternoon, March 11
Session Chairman—Ken Hollingsworth

"Recommended Standards of Office Lighting," by J. W. Greenlaw, Lighting Materials Ltd., Winnipeg, Manitoba. (Discussion leader, H. J. Ashbee.)

"Importance of Fixture Manufacturers Publishing Illumination Design Data," by J. H. McCulloch, Sunbeam Lighting Co., Los Angeles, Calif. (Discussion leader, Paul Davis.)

"Color—a New Dimension in Lighting," by G. B. Buck II, General Electric Co., Nela Park, Cleveland, Ohio. (Discussion leader, Jack De-Ment.)

INLAND EMPIRE delegates to the Pacific Northwest Regional Conference: David Mozes, Chairman, is center, light suit.

Several outside inspection trips were also features of the Conference; over 100 of the delegates took part in the planned tours. The field trips included a demonstration of the Portland General Electric's Street Lighting Laboratory; a visit to the famed Sanctuary of Our Lady of Sorrows, an illuminated grotto carved from living rock on the face of a sheer 160-foot mountain cliff; and a guided tour through Bonneville Dam. Scheduled trips through Portland's two newspaper plants were effectively cancelled by the Web Pressmen's Union whose newspaper strike was in progress at the time of the Conference. Local news coverage of the Conference was hampered by the strike, but outlying papers gave it front-page space for the local affair of importance that it was.

Entertainment features of the Conference included well-organized luncheons, fashion shows, sight-seeing trips, and a banquet and dance on the closing evening.

The Conference also afforded an opportunity for a serious Board of Managers meeting of the four Chapters of the Region, to exchange ideas for effective local administration of the Society. The special meeting was attended by National President Lee E. Tayler who presented to the joint Boards national Society plans and problems.

A more thoroughly-planned meeting than the Pacific Northwest Regional Conference would be hard to conceive. Several months before the date of the Conference Chairman R. E. Lange of the Oregon Section appointed Jerry Collins as General Conference Chairman. Mr. Collins established a committee organization designed to plan efficiently for every detail of the meeting. The success of the Conference and the "effortlessness" of its operation testifies to the wisdom of such organization. The local members heading the various committees were:

Assistant	Leo E. Chaffin
Technical Programs	W. E. Potter
Advisory	A. H. Greisser
Budget	J. Dan Webster
Publicity	C. D. Ham
Reservations	T. W. Fitch
Registration	Paul Norstrum
Entertainment	D. O. Bergey
Properties	Sam Sposito
Ladies' Entertainment	Louise Gronnert
Guided Tours	T. W. Fitch

The Section's planning of the Conference did not stop, however, with

PUGET SOUND members attending the Pacific Northwest Regional Conference. Chairman K. E. Hollingsworth, Chairman, fifth from left, is to immediate left of President Lee E. Tayler. Seventeen delegates from this area attended the meeting.

the present meeting. For the guidance of the other Conference planners, a complete set of files of all pertinent correspondence, minutes, and recommendations of various committee meetings and actions was prepared in kit form and forwarded by the Oregon Section to the Host Chapter for the next Regional Conference.

New Southern Chapters Receive Charters

Two new Chapters in the Southern Region were officially presented with I.E.S. Charters, and historic gavels, at special Charter-Night ceremonies recently.

The new Tennessee Valley Chapter, located in Nashville, Tennessee, held its historic meeting there on March 21, 1949. Highlight of their first official meeting was the presentation of their I.E.S. Charter, made by the guest of honor, Regional Vice-President J. B. Browder. Also presented was a special gavel, gift of the Mother Lode Chapter, next "youngest" I.E.S. Chapter.

Officers of the new Tennessee Valley Chapter are:

Chairman, Bullock Taylor, Tennessee Valley Authority, Nashville, Tenn.

Secretary, Collin Finney, Braid Electric Co., Nashville, Tenn.

On March 23, similar ceremonies officially ushered in the new Carolinas Chapter, at Charlotte, N. C. Guest of honor was Regional Vice-President Browder, who presented this Charter also, together with a gavel presented by the Tennessee Valley, the next youngest Chapter by only three days. Territory embraced by the new Carolinas Chapter covered all of both Carolinas; officers elected were:

CAROLINAS CHAPTER received Official Charter at special ceremonies, Charlotte, N. C., March 23. Left to right, front row, D. W. Woodside, Roy A. Palmer, Chairman of the Chapter, and Robert F. Allen. Standing, left to right, S. G. Hibben, E. A. Fargis, J. B. Browder, Regional Vice-President, and J. W. Edwards.

Chairman, Roy Palmer, Duke Power Co., Charlotte, N. C.

Secretary, Robert F. Allen, Lighting Products Co., 1337 E. Morrehead St., Charlotte, N. C.

Engineering Enrollment Returning to Normal

The enrollment in engineering colleges indicates a rapid readjustment back to pre-war trends, according to an analysis made by S. C. Hollister, Dean of Engineering at Cornell University, published in the March issue of the *Journal of Engineering Education*. Enrollment figures collected by the American Society for Engineering Education show a freshman enrollment this year of 48,000 in engineering, representing a sharp decline from the enrollment of over 80,000 in 1946. The present freshman class is slightly greater than the trend of freshman registration in pre-war years. By 1952-53 it is anticipated that the number of engineering graduates will reach the normal trend extended from pre-war years. Although the enrollments in upper classes are abnormally large due to a large veteran enrollment, Dean Hollister pointed out that these are, in considerable part, replacements for the large deficits during the war years. This deficit has been borne out by the acute shortage of engineers in the post-war era. The problem of absorption of engineers in industry, if there be one, will develop next year or the year after. Beyond 1951-52, the number of engineering gradutes each year will return to pre-war trends or, perhaps, fall slightly below these trends due to the decline in birth rate during the depression years of the 1930's.

With stable economic conditions, Dean Hollister stated, the prospects for freshmen entering in 1949 should be good. A number of factors, such as the ones of far-reaching scientific and technical advances of the past few years, the use of engineering graduates outside the proximity of professional resources — all of these and many others may cause a sharp upward trend in engineering employment. It also is conceivable that a rapid development of a national emergency might actually find us with a short supply of engineers.

In recent months statements have appeared in the public press that the rate of trained engineers is far beyond the demand and that unless some means of replacing the number of engineering graduates is invoked, the prospects for many young engineers

TENNESSEE VALLEY Charter presentation made at Nashville, March 21. Left to right: J. B. Browder, Regional Vice-President, presenting Charter, J. L. Booker, E. E. Parks, Bulloch Taylor, Chairman of the new Chapter, Walter Nash, and Collin Finney, Secretary.

of finding suitable employment in the profession will be poor. Reliable information on this subject, however, does not bear out statements being made.

New Lighting Competition Announced

A nationwide lighting competition, sponsored by General Electric Company in connection with the electrical industry's comprehensive Planned Lighting Program, was announced early in April by G. E. Lamp Dept., Nela Park, Cleveland. The competition features 192 cash awards having a total value of $21,000.

The awards, termed "Certificates of Appreciation," are in amounts of $100 and $150. Eligible to receive the $100 awards are individuals who will have played key roles in the planning, selling, and supply concerning the 36 outstanding Planned Lighting installations of 1949. The $150 certificates are being offered as additional awards to persons submitting reports of winning installations.

Twenty-four of the winning installations will be in the commercial and industrial lighting classifications. The remaining 12 will be in the residential lighting category.

The 1949 Planned Lighting cash awards, the announcement stated, are intended to serve as "an expression of appreciation to those who strive to bring maximum lighting benefits to users of G-E lamps."

Complete details concerning the competition, such as contest rules and names of persons appointed to judging committees, are to be announced at an early date, the sponsors of the Planned Lighting awards declared. Other highlights regarding the G.E. competition are these:

Awards will be based on reports of lighting installations submitted to General Electric's Lamp Department not later than December 31, 1949. The installations may be either initial lighting of new buildings or the relighting of existing buildings.

In the commercial and industrial classifications, the 24 awards will be divided as follows: eight for installations in communities of 5,000 population or less; eight in communities in the 5,000 to 100,000 population class; and, eight awards for installations in cities of 100,000 and over.

Awards will be given for any type of commercial or industrial lighting installation—in stores, offices, schools, factories, service stations, theaters, restaurants and the like. However, not more than 4 awards in any of the 3 population groups will be given for any one type of installation. Among persons eligible to receive awards in the commercial and industrial classifications are lighting representatives of electric service companies, wholesalers' salesmen, architects, lighting designers, and electrical contractors.

In the residential classification, the twelve awards will be divided into 3 groups of 4 awards for homes in communities according to the same population brackets established for the commercial and industrial competition.

Standardized Membership Qualifications Proposed

Though final action has not yet been taken, the Committee on Professional Recognition of Engineers' Council for Professional Development is well on the way to agreement on a recommendation to national engineering societies that membership grades and minimum qualifications for membership be standardized.

Three essential grades of membership are contemplated: Member, Associate Member, and Student Member, with two other grades suggested for those societies that may wish to adopt them: Fellow and Affiliate.

A Member shall have had (1) an engineering degree, with at least four years of increasingly important engineering experience indicative of growth in engineering competency and achievement and of a satisfactory character, at least two years of which shall have been in responsible charge of engineering work. Or, (2) if not a graduate he shall have had at least ten years of engineering experience satisfactory to the society. A license to practice professional engineering, or the passing of an examination prescribed by the governing board of the engineering society involved may be accepted as qualifying experience. Teaching may also be considered as qualifying experience. If not an engineering graduate, graduation from a natural or physical science curriculum may be acceptable, though such training should preferably qualify a man for Associate Membership.

An Associate Member shall be merely a graduate of engineering or physical science curriculum, with no experience required; or, if not a graduate, should have had at least six years of professional experience.

A Student Member shall be an undergraduate or graduate engineering student in the professional field of the society.

A Fellow is purely an honorary grade, for engineers of distinction for which the member makes no application.

The Affiliate grade would apply to those who are not professional engineers, but who co-operate with engineers in the advancement of engineering knowledge and practice.

Comment on the above suggestions is invited by the Secretary of ECPD, 14th floor, 29 West 39th Street, New York 18, N. Y. A final meeting of the committee to discuss the subject is planned for late May.

Lamme Medal Award

The 1948 Lamme Medal of the American Institute of Electrical Engineers has been awarded to Dr. V. K. Zworykin, Vice-President and technical consultant, RCA Laboratories Division, Radio Corporation of America, Princeton, N. J., "For his outstanding contribution to the concept and design of electronic apparatus basic to modern television."

The medal will be presented to Dr. Zworykin at the Summer General Meeting of the Institute to be held in Swampscott, Mass., June 20-24, 1949.

The Lamme Medal was established through a bequest of Benjamin Garver Lamme, who was chief engineer of the Westinghouse Electric and and Manufacturing Company from 1903 to his death in 1924. Beginning in 1928, the medal has been awarded annually for high achievements in the development of electric apparatus or machinery.

Illuminating Engineering Reprints

To provide readers as well as authors with quantities of reprints of articles, it is planned to hold future issues of ILLUMINATING ENGINEERING in type for about four weeks following publication. Orders should be submitted to the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y. As the cost of reprinting varies with the number of pages and the quantity ordered, prices for a specific item will be submitted on request. While many authors follow the practice of getting a small quantity of reprints for their own use, the Publications Office does not in general have sufficient extra copies for possible continued demands.

LIGHTING CALENDAR

Society Events

May 11, 1949—Meeting of I.E.S. Executive Committee, Hartford, Conn.

May 12-13, 1949—Northeastern Regional Conference, Hartford, Conn.

May 19, 1949—Milwaukee Chapter Spring Illumination Conference, Blatz Hospitality Room, 3112 West Highland Blvd., Milwaukee, Wisconsin.

May 23-24, 1949—Great Lakes Regional Conference, Rochester, N. Y.

June 6-7, 1949—East Central Regional Conference, Harrisburg, Pa.

June 8, 1949—Meeting of I.E.S. Council, 51 Madison Avenue, New York, N. Y.

June 9, 1949—Local Activities Conference, New York, N. Y.

June 9, 1949—Meeting of Council Executive Committee, New York, N. Y.

July 13, 1949—Meeting of I.E.S. Executive Committee, Philadelphia, Pa.

September 19-23, 1949—National Technical Conference, French Lick Hotel, French Lick, Ind.

Industry Events

May 2-4, 1949—American Society of Mechanical Engineers, Spring Meeting, Hotel Mohican, New London, Conn.

May 2-6, 1949—National Electrical Wholesalers Association, 41st Annual Convention, Netherland Plaza Hotel, Cincinnati, Ohio.

May 7, 1949—Eastern Electrical Wholesalers Association, Dinner and Dance, Hotel Astor, New York, N. Y.

May 16-19, 1949—National Fire Protection Association, 53rd Annual Meeting, Fairmont Hotel, San Francisco, Calif.

May 30-June 10, 1949—Canadian International Trade Fair — Exhibition Grounds, Toronto, Canada

May 31-June 2—Edison Electric Institute, Annual Meeting, Traymore Hotel, Atlantic City, N. J.

June 5-9, 1949—The American Society of Refrigerating Engineers, 36th Spring Meeting—Cruise; St. Lawrence and Saguenay Rivers starting from Montreal

June 20-22, 1949—American Society of Heating & Ventilating Engineers, Semi-Annual Meeting, Minneapolis, Minn.

June 10, 1949—Society of Motion Picture Engineers Regional Meeting, Toledo, Ohio.

June 20-24, 1949—American Institute of Electrical Engineers, Summer General Meeting, New Ocean House, Swampscott, Mass.

June 27 to July 1, 1949—New York Lamp Show, Hotel New Yorker, New York, N. Y.

June 28-30, 1949—Canadian Electrical Association, Annual Convention, Banff Springs Hotel, Alberta, Canada.

July 2-9, 1949—New York State Association of Electrical Contractors & Dealers, Inc., Golden Anniversary Convention, Saranac Inn, N. Y.

August 23-26, 1949—American Institute of Electrical Engineers, Pacific General Meeting, Fairmont Hotel, San Francisco, Calif.

August 26 to September 10, 1949—Engineering and Mining Exhibition, London, England.

October 11-14, 1949—American Standards Association, Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

October 17-21, 1949—American Institute of Electrical Engineers, Netherland Plaza Hotel, Cincinnati, Ohio.

October 24-28, 1949—37th National Safety Congress, Chicago, Ill.

November 13-18, 1949—National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

December 4-7, 1949—The American Society of Refrigerating Engineers, 45th Annual Meeting, Edgewater Beach Hotel, Chicago, Ill.

LOCAL MEETINGS

NEW YORK SECTION

The New York Section, through one of its two active Forum organizations, has been consistently "disseminating knowledge" to a group not generally reached through regular Society channels. For the second successive year the Section's Residence Lighting Forum has conducted a practical course on home lighting directed to the needs and interests of interior decorators—a group probably in greatest need of lighting knowledge and one in a position to put such knowledge into practice. Some 69 men and women attended the five sessions. Of these the majority were practicing decorators, with utility, department store people, manufacturers, home economic students, and magazine publication personnel also represented, in that order.

One especially practical feature of the course was the definite "how to do" lighting recommendations made by each lecturer; in one lesson a lighting problem (lighting a picture) was solved by the class itself through techniques learned in earlier lectures.

Another valuable feature was the envelopes of pertinent literature distributed to the students at each session. These included I.E.S. Lighting Data Sheets, I.E.S. Recommended Practices, reprints, booklets on color, home lighting, home wiring, lamp types, and numerous other material of help to the practicing decorator.

It is interesting to note that fifteen of the men and women taking the course requested application for membership in the New York Section Residence Lighting Forum.

Outline of the course on "Practical Methods of Lighting Residential Interiors" included:

March 1—The Tools of Lighting, by Lillian Eddy, General Electric Co., New York, N. Y.

March 8—How Lighting Affects Mood and Interior Colors, by E. W. Commery, General Electric Co., Nela Park, Cleveland.

March 15—Harmonizing Lighting and Decoration, by Mary Webber, General Electric Co., Nela Park, Cleveland.

March 22—How to Plan for Built-In Installations, by Myrtle Fahsbender.

March 29—Solutions to Specific Lighting Problems by Francis P. D'Esopo, The Wiremold Co., Hartford, Conn., Priscilla Presbrey,

Westinghouse Electric Corp., Bloomfield, N. J., Thomas S. Kelly, Lighting Consultant, New York, N. Y.

The course was under the direction of Lillian Eddy, Chairman of the Forum's Educational Committee. Serving with her were Ruby Redford, Chairman of the New York Section Residence Lighting Forum; Jan Reynolds, Treasurer for the course; Marion Browne, Elizabeth Kaufer, Myrtle Fahsbender, Mabel Taylor, Rosalind Clarke, Adelaide Ehrich, Thomas S. Kelly, Frank E. Brown, and Caroline Horn, Chairman, New York Section.

Central New York Chapter

A special dinner meeting of 33 leaders of the Central New York Chapter was held March 11, to honor the visiting Regional Vice-President, W. A. Stannard. The meeting was held at the Howard Johnson Restaurant outside of Syracuse, N. Y. Mr. Stannard addressed the gathering on two subjects—"The Illuminating Engineering Society Benefits You," and "Lighting Service Today and Yesterday."

Montreal Section

The Montreal Section has this year undertaken a series of extracurricular Forums which have proved to be an important service in that area. In addition to their regular meetings the Section has conducted full-scale Forums, covering full-day or half-day programs on important phases of lighting.

Another such forum was held in Montreal on March 30, on "Lighting and Lamps in Industry." Covering an afternoon and evening at the plant of Canadair Ltd., the meeting was conducted by the Montreal Section, under the direction of R. A. Eshelby as Forum chairman. Directed primarily to non-members, the Forum was well attended, and enthusiastically received. Subjects presented at the Forum included:

"Recommended Practice of Industrial Lighting" by J. Thomas, Chairman of Montreal Section.

"Basic Considerations in Industrial Lighting Design," by W. J. W. Smith, Shawinigan Water and Power Co.

"Lighting in Hazardous Locations," by J. R. Jeffrey, Crouse-Hinds Co. of Canada Ltd.

"Illumination and Production" by G. G. Cousins, Hydro Electric Power Commission of Ontario.

"Good Maintenance Pays," by H. John Ward, Holophane Consulting Representative.

"Infrared Lamps in Industry" by W. K. Wiley, Northern Electric Co., Ltd.

"Light and Colour in Industry" by J. de Carufel and A. W. Barton, Hobbs Glass Ltd.

"The Brains Trust," a panel of experts to answer questions on any aspect of industrial lighting.

A dinner was held at the conclusion of the session, after which all present were conducted through the Canadair plant.

THE "BRAINS TRUST" of the Montreal Section Lighting in Industry Forum. Left to right, Frank R. Jeffrey, J. deCarufel, A. H. Barton, R. A. Eshelby, George C. Cousins, W. K. Wiley, R. Hendershot, A. J. Hoad.

IT SEEMS TO ME

The Fallacy of the Louverall Ceiling

L. Koenig:* It will be interesting to note manufacturers' comments on the rather prejudiced article "The Fallacy of the Louverall Ceiling," March Illuminating Engineering, p. 169, mentioning "horrible" examples and "fallacious" statements.

The comparison of lighting practices with the crude equipment specified and the data derived therefrom appears to lack proof and one has the feeling that the writers are trying to be convincing with mere words.

It would seem to me that various types of shielding such as plastic, metal, wood, etc., as well as diffusion and transmission factors for various makes of translucent panels should have been considered in the final analysis.

In view of the fact that very little dimensional data has been included in the article, it is impossible to check whether or not recommended heights and spacings above and below the louverall units have been employed. I cannot for the life of me imagine why the experiments were made with bare lamps when normal installation calls for fixtures so as to eliminate glare and provide for distribution.

Furthermore, since the eggerate louver was made of white cardboard it is safe to assume that the specular reflections, that is to say, the inter-reflections created inside each louver opening and the accompanying "funnel" effect will not diffuse as stated, but rather increase the incident illumination of the bare lamps used in the experiment.

I am looking forward to more "illuminating" data on the subject and other comments.

*Roselle, N. J.

What, Why and How

Howard M. Sharp:* A study of contributed papers and committee reports over the years of the Society's existence will reveal a high degree of technical competency and scientific searching for truth. Such material comprises a record for humanity but also serves the more immediate purpose of raising the level of knowledge of Society members and others, and by this means improving the contribution which lighting makes to the processes of civilization.

This is the normal process in any branch of science or technology. Any one engaged in it acquires knowledge from many sources and in many forms, and synthesizes it through the daily process of living and experiencing. When confronted with a problem, or situation, this knowledge and experience is brought to bear, and a solution attempted. It makes no difference whether the problem is sales, finance, social, emotional or technical; through the mysterious processes of the human brain, the facets of knowledge are marshalled to the task. One may make both conscious and subconscious decisions which if required to document would impose a task of insurmountable pro-

*Consulting Engineer, Buffalo, N. Y.

portions. Why? Simply because steady endeavor in any field produces a reservoir of decision patterns that allows for almost instant acceptance or rejection of alternatives without the laborious re-examination of pros and cons.

Such actions are in short the mark of a trained man.

Let us retrace our steps a bit. Men engaged in a common endeavor gradually develop a nomenclature and style of communication that serves to transmit ideas with a high degree of efficiency. Suppose such a group were to be joined by one not familiar with the group activity. Suppose a point is made or a categorical statement put forth which is understood and accepted by the group, but the stranger asks for enlightenment. Does it require much imagination to foresee the long explanation, the assembling of facts, the simplification of language, the weighing of statements, that go into making the matter clear to the stranger? If in addition the stranger is given an assignment to take the material given him and apply it to some pertinent situation is it not apparent that what is given must be so condensed, so rounded off, so abridged, and also so fortified with simple illustrations and homilies, as to make it remembrable and maybe understandable to a still more uninitiated third party?

What has been described as essentially a small group action, is to illustrate the situation with respect to "Recommended Practices" put forth by the Society. These practices are simply an attempt to educate in one easy lesson, in any given aspect of lighting application. As the subject under consideration involves more and more complex aspects of illumination so do these Practices become more hedged about with yeas and nayes, and so does their form and content become less incisive. When there is added to this the attempt to persuade, with prospects of advantage and hints of loss, the result is a wordy document that commands no real respect in any informed quarter.

The layman still does not understand the subject. The person with an elementary knowledge of lighting almost always arrives at the wrong conclusions. Our members and industry allies are confronted with a repetition of generalities that does not build genuine respect and in fact occupies mental space that could better be devoted to the genuine article.

On the other hand, when the Society speaks directly to its members or informed associates the points are directly made and documented without in each instance attempting to fill in the background or delineate all the alternatives. These works have character. Reports of the "Q & Q" Committee, Lighting Performance Recommendations, Testing Specifications, etc. are cases in point.

But when we attempt to teach the public how to perform their own illuminating engineering we lose character, because being conscious of a certain responsibility we try to safe-guard statements and open loopholes of escape, all without offending anyone. Likewise, these "Recommended Practices" seem inevitably to fall into the style, and copy the technique of, the modern advertising copy writer.

There is no intent to say that such is reprehensible, but it has no place in the life of a technical society.

The plain and unvarnished fact is that the Society as a group tends to go two ways at once. The reason for its being rests upon technology but whatever measure of success has been attained has encouraged efforts to utilize the prestige that goes with this success, in the direction of mass education. It should be clear that it is impossible to make a lighting expert of the man on the street. It should also be clear that the health of the lighting industry depends upon a strong and growing technical foundation. Upon this foundation can be built the very necessary and vital sales and promotional activities without which the industry could not exist.

Look about at technical professions we know well. The architects, for example, are not busily publishing methods whereby anyone can be his own designer. They devote their attention to improving the ability of architects and leave it to the trade press and the industry to stimulate the public to a demand for and appreciation of professional ministrations. Mechanical engineers do not sponsor "Recommended Practices" for the air conditioning of this and that space. They go about uncovering facts and disseminating them to the industry, leaving to qualified hands the stimulating of demand for equipment and services. There is no need to refer to the professions of medicine and law as ever promulgating books on self medication or lay methods of pleading a case. But the great pharmaceutical companies educate on general health and publicly acknowledge the medical profession at the same time, while the famous dental slogan "Clean your teeth twice a day—see your dentist twice a year" is a perfect example of industry and professional teamwork.

It can be done in the lighting industry if the will and the vision of a few leaders can be motivated.

It is self evident that one's friends can speak more highly and more convincingly about one's abilities than the person himself. So too with the Society. Through committee reports and research projects we can say *what* to do. Let others far more skillful say *why* to do it, and organize and carry through the means whereby this message reaches and moves people. The Edison Electric Institute and NEMA, for example, can very well do this job. Let the men and women of the industry synthesize the facts we uncover, and show the consumer how to achieve the desired result. This can be done through steady training at various levels of membership occupations. We now have a large volume of "lighting courses" but they are generally on the "fundamentals" level. It is time we moved up, and if this were done the gaps in our knowledge would become painfully evident, producing a demand that would keep research and engineering committees busy.

It should be taken as a sobering fact that the Society and the lighting industry does not enjoy the fancied esteem among other professions that border on ours. They see in too many of our published works the compromising of principles and the deference to current promotional activities that result from our habit of trying to go two ways at once. We do too much "talking down" in this process and thus conceal the real import and potentialities of lighting. A quotation from Charles D. Gibson can apply with equal force to any lighting situation: "The real factors involved in the creation of a comfortable and efficient seeing environment are so many and so involved that none but those dealing constantly in the research in this field have any idea of their multiplicity and inter-relationships. He who glibly gives the answer to the school lighting problem does so in abysmal ignorance."

Orders Being Taken for Data Sheet Series XIV

Orders are being taken at I.E.S. Headquarters for the first seven Lighting Data Sheets of Series XIV.

While these Data Sheets will appear regularly in the pages of ILLUMINATING ENGINEERING as a service to members, the sheets printed on especially heavy coated paper and punched for binder use may be obtained only by regular subscription. (See page 12A.)

Lighting Installations of Special Interest

State Assembly Chamber, Sacramento, California

The following is a condensation of an article by Mr. Thayer B. Farrington of the Thompson Electric Co., Cleveland, Ohio, covering the interesting problems encountered in the relighting of the State Assembly Chamber at Sacramento, California.

The installation problems presented in the relighting of the State Assembly Chamber of the State Capitol at Sacramento, California, required new ideas for their solution.

Obtaining adequate light (40 ft-c at desk level) with low temperature rise consistent with the capacity of the air-conditioning system in the high summer temperature at Sacramento was the first problem, and therefore fluorescent lighting was indicated.

The next was that of providing the necessary lumens with minimum adverse effect acoustically and architecturally. This could only be answered by high-positioned luminaires of special design arranged in continuous rows, each unit containing more tubes than are usually found in commercial fixtures.

The maintenance of this lighting equipment at low cost, whenever needed and without using scaffolds or platforms, seemed the most difficult problem as there was no false ceiling with space above sufficiently high to permit hoisting into it, whole or part rows of fixtures and provide adequate working headroom. Cut-out hangers proved to be the solution to this problem.

The lighting plan as finally developed for the 73′ by 70′ chamber consists of 5 rows of fluorescent units spaced on 14′ centers running transversely across the chamber, so mounted that the tops of the units are about 6″ below the ceiling and the bottom about 33′ above the floor. Total load is 15 kw. Each unit length of luminaire incorporates either 3 or 6 3500° white fluorescent lamps. The units are combined in luminaires of either 8′ or 12′ lengths. Shielding of the tubes is provided by means of prismatic lenses.

End clearance between these long units is approximately 3″ to permit lowering and raising any individual unit without interference with adjacent units. With this small clearance and high mounting, the effect is that of continuous rows.

Each of the 36 large lighting units is supported from two cut-out hangers, reinforced with oversize axles and connecting bolts to safely handle fixture weights of 400 lbs. The large center fixtures, with 12 tubes and necessary ballasts, weigh approximately 350 lbs. each.

The operating cables for the hangers are $\frac{1}{8}$″, 7 x 19, preformed aircraft cable, and they are dead-ended in the lower member of the hangers.

The operation of lowering or raising a fixture is handled by means of two winches mounted at 90° to each other on a portable winch stand placed over traps in the floor of the room above the assembly chamber. Both operating cables for the two hangers on a fixture unit are accessible through the same floor trap. This is made possible by correctly located intermediate pulleys between the floor trap and the hangers. Each winch has its own winch line, also of the $\frac{1}{8}$″ cable, which has a tensile strength of 2000 lbs., sufficiently long to lower the lighting unit to the floor level of the Assembly Chamber. These winch lines are connected to the operating cables by means of special connecting links. To avoid the heavy stress on these links when latching and unlatching the hangers, the operating cables are provided with a served-in fastening loop for securing them to the terminal hooks and then sufficient additional length when attached to the winch line; there will be at least three wraps of operating cable including the links, snubbed on the winch drum.

As the operation must be handled "blind," i.e., without being able to see through the operating floor, an intercommunicating 'phone is used to receive instructions from the maintenance man on the assembly floor.

To make possible complete check test of any unit when it is lowered for servicing, a special test block was

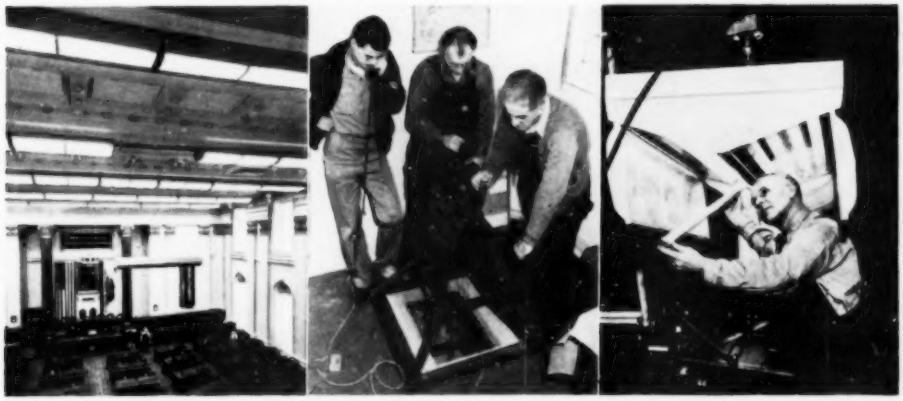


Photo at left shows the State Assembly Chamber, California State Capitol, at Sacramento, California, under the new fluorescent lighting installation. One 8-foot 12-tube fluorescent fixture, in process of being lowered for servicing, is guided by the service man on the floor, using intercommunicating telephone. Center photo illustrates the method of lowering and raising the special fluorescent fixtures through the traps in the floor of the room above the Assembly Chamber. Note the two winches mounted on the portable winch stand located over one of the traps in the floor. At right, a disconnected and lowered fixture is undergoing servicing and testing, energized by special test blocks. ***Photographs courtesy of Hub Electric Co., and Thompson Electric Co.***

developed corresponding to the upper member of the hanger. This is connected by extension cord to plug-in receptacles, and latches in place on the lower member to feed the necessary current to the fixture for a complete test.

When the fixtures are lowered to desk level for servicing, they are readily accessible for soap-and-water washing, retubing, and repairs as needed.

New Orleans Lighting Center

"Light for Profit"—a new idea in commercial lighting centers—is the theme of the new center recently opened on the first floor of the New Orleans Public Service, Inc. Highlights of it have been reported by E. H. Fremaux and W. A. Feuillan, Jr., of that company. The new Center is not just one "lighting installation, of special interest," but some thirty installations, so designed that architects, consulting engineers, dealers and owners of stores, offices and industrial plants may see the latest lighting equipment under the exact conditions of their installation.

The Center is the result of happy cooperation by manufacturers, through their representatives, jobbers and the New Orleans Public Service, Inc., to bring the "planned lighting" story to consumers or users; store, plant and office owners. On display is a complete cross-section, as it were, of up-to-date lighting fixtures. Buyers can see and study direct, indirect, semi-direct, semi-indirect, or a combination of two or more systems, can compare incandescent, fluorescent, slimline, cold cathode, etc., individually or in combination. Lighting can be studied, evaluated, judged as the flexibe tool that it is, mistakes can be avoided and final results pre-determined.

It is not surprising that the new Lighting Center has been welcomed by business men of New Orleans as well as by utility and jobber salesmen. These last use the Center as a showroom, as a base of operations, as it were, where their prospects can see examples of modern lighting, the actual equipment used to produce given results, and where they can buy planned lighting instead of fixtures, as such.

Architects also have welcomed the idea of studying actual fixtures instead of pictures, where their own clients can see what specifications and blue prints can only suggest. It is reported that they are using the Center in increasing numbers.

Previews of the Center have already been held to acquaint distributors, manufacturers' representatives, architects and consulting engineers with the display and its features. They have been invited both personally and by letter to use the facilities of the Center to obtain more and better installations of modern illumination in commercial and industrial establishments.

Plans call for periodic change of fixtures and equipment. An opportunity will be given all accredited manufacturers to show their products, new developments, etc. This and the frequent replacement of display is planned to keep the showing up to date and help maintain public and user interest.

NEW MEMBERS

At the meeting of Council held on April 2, 1949, the following were elected to membership:

BALTIMORE CHAPTER

Associate Member:

Coblentz, Joseph A., Union Metal Mfg. Company, Baltimore, Md.

BRITISH COLUMBIA CHAPTER

Associate Members:

Horwood, B. I., Canadian Laco Lamps, Ltd., Vancouver, B. C., Canada.

Smythe, A. F., Greater Victoria School Board, Victoria, B. C., Canada.

Student Member:

Reid, J. M., University of British Columbia, Vancouver, B. C., Canada.

CAPITAL SECTION

Associate Member:

Kern, Oliver S., Office of the Municipal Architect, Washington 1, D. C.

CAROLINAS CHAPTER

Member:

Allen, Robert F., Lighting Products, Inc., Charlotte, N. C.

CENTRAL NEW YORK CHAPTER

Member:

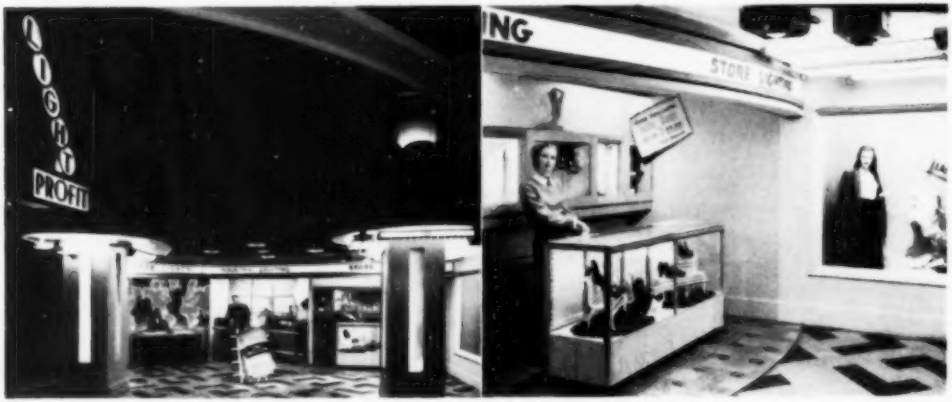
Lacy, James A., New York State Electric & Gas Corp., Ithaca, N. Y.

CHICAGO SECTION

Members:

Bardsley, Robert V., Sylvania Electric Products Inc., Chicago, Ill.

Kerr, A. W., A. W. Kerr and Associates, Chicago, Ill.



New Orleans Lighting Center. Right, Store lighting is effectively demonstrated, both general interior illumination and display. Show window, show case, niche, etc., lighting of varying levels can be shown. Spot, flood and silhouetting techniques can be studied. At left, overall view of the new Lighting Center "Light for Profit," at the New Orleans Public Service Co. Latest applications of lighting techniques are on display.

O'Donnell, Joseph J., Board of Education, Chicago, Ill.

Associate Members:

Florek, Edward J., Westinghouse Electric Supply Co., Chicago, Ill.

Hultgren, W., Hultgren Electric Corp., Chicago, Ill.

Hultgren, W., Jr., Hultgren Electric Corp., Chicago, Ill.

Ligon, James F., Chicago Lighting Institute, Chicago, Ill.

Martin, B. J., B. J. Martin & Company, Chicago, Ill.

Peterson, R. W., Hultgren Electric Corp., Chicago, Ill.

Student Members:

Bevan, Roy E., University of Illinois, Urbana, Ill.

Karraker, Wallace G., University of Illinois, Urbana, Ill.

Lozano, Edmund, University of Illinois, Urbana, Ill.

Mangold, Willis N., University of Illinois, Urbana, Ill.

Cleveland Section

Member:

Bowditch, F. T., National Carbon Company, Cleveland, Ohio.

Associate Members:

Canfield, Donald M., Sylvania Electric Products, Inc., Cleveland, Ohio.

Dennison, C. N., Jr., Dennison Electric Co., Cleveland, Ohio.

Einheit, Herbert C., Einheit Electric Construction Company, Parma, Ohio.

Eisenhaver, William A., General Electric Company, Cleveland, Ohio.

Godwin, Curtis B., Westinghouse Electric Corp., Cleveland, Ohio.

Gunn, John O., Holdenline Company, Cleveland, Ohio.

Holmes, Robert E., General Electric Company, Nela Park, Cleveland, Ohio.

Molnar, William J., Brecksville, Ohio.

Morgan, Maxwell C., Westinghouse Electric Corp., Cleveland, Ohio.

McMillan, Harry A., Youngstown Lamp Works, General Electric Co., Youngstown, Ohio.

Nichols, Anthony, City of Cleveland, Cleveland, Ohio.

Robison, Wendall C., General Electric Co., Nela Park, Cleveland, Ohio.

Stofer, Gordon F., Edwin F. Guth Company, Cleveland, Ohio.

Student Members:

Kraina, John J., Case Institute of Technology, Cleveland, Ohio.

Trenbath, Herbert W., Jr., Case Institute of Technology, Cleveland, Ohio.

Connecticut Chapter

Associate Member:

Gordon, Robert J., The Connecticut Power Co., Manchester, Conn.

Domestic Non-Section

Student Members:

Bolian, Sam, Jr., Mississippi State College, State College, Miss.

Buchanan, William D., Mississippi State College, State College, Miss.

Byars, William F., Mississippi State College, State College, Miss.

Catledge, Robert C., Mississippi State College, State College, Miss.

Clark, Lawrence E., Mississippi State College, State College, Miss.

Hickman, Lawrence H., Mississippi State College, State College, Miss.

Lee, Robert Emmett, Mississippi State College, Starkville, Miss.

McMullen, H. G., Mississippi State College, State College, Miss.

Manning, Billy T., Mississippi State College, State College, Miss.

Maxey, Edra Lee, Jr., Mississippi State College, State College, Miss.

Shields, E. W., Mississippi State College, State College, Miss.

Sloan, Robert T., Mississippi State College, State College, Miss.

Smith, Rayburn E., Mississippi State College, State College, Miss.

Stinson, Mitchell O'Neal, Mississippi State College, State College, Miss.

Watkins, Leigh, Mississippi State College, Starkville, Miss.

Wheeler, Robert Joseph, Mississippi State College, State College, Miss.

Willis, Robert C., Mississippi State College, State College, Miss.

Eastern Pennsylvania Chapter

Associate Members:

Aicher, John B., Heyl-Bond-Miller, Allentown, Pa.

Grim, Russell H., Grim Electric Co., Boyertown, Pa.

Housum, William T., Hen. Johnston, Inc., Reading, Pa.

Murphy, Harbert T., General Electric Co., Allentown, Pa.

Nelmes, Jack T., Pennsylvania Power & Light Co., Bethlehem, Pa.

Phillip, John D., Phillips Electric Co., Bethlehem, Pa.

Shumbat, Joseph, Shumbat Electric Co., Allentown, Pa.

Zboyosky, W. J., Pennsylvania Power & Light Co., Bethlehem, Pa.

Florida Chapter

Members:

Bollinger, N. H., Florida Power & Light Co., Miami, Fla.

Carter, T. E., Florida Power & Light Co., West Palm Beach, Fla.

Cox, Ray D., Florida Power & Light Co., West Palm Beach, Fla.

Associate Member:

Boesch, John C., Westinghouse Electric Corp., Miami, Fla.

Georgia Section

Associate Members:

Cain, L., Lester Cain, Inc., Atlanta, Ga.

Sweatman, Carroll C., Jr., Georgia Power Co., Atlanta, Ga.

Indiana Chapter

Associate Members:

Chaney, Earle R., City Utilities, Fort Wayne, Ind.

Drury, Joseph A., Jr., Sylvania Electric Products, Inc., Indianapolis, Ind.

Kahn, Robert D., Capital Paper Co., Indianapolis, Ind.

Inland Empire Chapter

Associate Members:

Baldwin, Ernest E., Baldwin Neon Sign & Lighting Co., Spokane, Wash.

Caferro, Edward M., Columbia Electric & Mfg. Co., Spokane, Wash.

Chamberlin, J. C., Chamberlin Electric Co., Spokane, Wash.

Gage, Frank, Noland Gage Electric Co., Walla Walla, Wash.

Hause, Frederick W., General Electric Supply Corp., Spokane, Wash.

King, Wilbur L., Washington Water Power Co., Spokane, Wash.

Lewis, C. E., Washington Water Power Co., Spokane, Wash.

Iowa Section

Associate Members:

Lenth, Lyle L., Oliver Corp., Charles City, Iowa.

Van Hauen, Orlo A., Crescent Electric Supply Co., Spencer, Iowa.

Michigan Section

Associate Members:

Allen, Burr H., Electrical Specialties Co., Detroit, Mich.

Edison, A. H., Edison Electric Co., Detroit, Mich.

Lawrence, A. E., Louis Redstone, 3510 Woodward, Detroit, Mich.

Lyons, Charles E., Burrough Adding Machine Co., Detroit, Mich.

Navarre, Thomas J., 3966 Buckingham Rd., Detroit, Mich.

Pierce, Orval W., Consumers Power Corp., Jackson, Mich.

Montreal Section

Member:

Richardson, P., The Robert Simpson Montreal Ltd., Montreal, Que., Canada.

Associate Members:

Baillie, A. D., Sherwin Williams Co. of Canada Ltd., Montreal, Que., Canada.

Brousseau, Maurice, Gaudiose Brousseau & Fils, Ltee., Quebec, Que., Canada.

Caron, W. R., Bizier & Caron, Ltd., Quebec, Que., Canada.
Fontaine, Henri G., Fernand Caron, 144 St. John St., Quebec City, Que., Canada.
Fortin, J. Thomas, Syndicat de Quebec Ltee., "Departmental Store," Quebec, Que., Canada.
Gendron, Roland, Roland Electrique Engineering, Limoilou, Quebec, Que., Canada.
Pednault, W., Quebec Power Co., Quebec, Que., Canada.
Quart, Harry, Jr., Modern Enterprises Registered, Quebec, Que., Canada.
Racine, Paul, Equipment Moderne Inc., Quebec, Que., Canada.
Rayworth, R., Rayworth Electric Service, Amherst, Nova Scotia, Canada.
Trottier, Clement, Guy Belanger, 1210 Benoit St., Montreal, Que., Canada.
Veilleux, L., Cartier Electrique Engineering, Quebec City, Que., Canada.

New England Section

Associate Members:
Holland, John, Sylvania Electric Products, Inc., Salem, Mass.
Hudson, Edward H., Cape & Vineyard Electric Co., Hyannis, Mass.
Silvey, Joseph, Centre Electric Supply Corp., Roxbury, Mass.

New Orleans Chapter

Associate Member:
Bryan, James J., W. J. Milner & Co., Atlanta, Ga.

New York Section

Associate Members:
Carroll, Edward S., Dept. of Public Works, City of New Rochelle, New Rochelle, N. Y.
Crocker, Kenneth G., Westinghouse Lamp Division, Bloomfield, N. J.
Fedigan, James J., Century Lighting Inc., New York, N. Y.
Langmack, Carl J., Pfaff & Kendall, Newark, N. J.
Levenstein, Robert, Ender Mfg. Corp., New York, N. Y.
Nodaj, Nicholas J., Jr., Atlantic Electrical Distributors, Inc., Hackensack, N. J.
Pfaff, Henry C., Jr., Pfaff & Kendall, Newark, N. J.
Ralston, Martin A., Kent Metal Mfg. Co., Brooklyn, N. Y.
Sutton, William K., Ender Mfg. Corp., New York, N. Y.
Walker, Bertram, B. Walker Electric Co., Brooklyn, N. Y.
Wallace, John J., Metropolitan Museum of Art, New York, N. Y.

Northern California Section

Associate Members:
Britton, Floyd C., W. B. Baker & Co., San Francisco, Calif.
Kullman, John T., Westinghouse Electric Supply Co., Oakland, Calif.
Nason, Robert M., Leader Electric Co., Oakland, Calif.
Peck, Norton A., Westinghouse Electric Supply Co., Oakland, Calif.
Schlapp, Fred W., 251 Kearny St., San Francisco, Calif.
Selover, W. H., Builders Electric Co., Hayward, Castro Valley, Calif.
Sweet, John S., Boyd Lighting Fixture Co., San Francisco, Calif.
Vaughan, James H., Pittsburgh Corning Corp., San Francisco, Calif.

Student Members:
Bilger, O. Korkmaz, Stanford University, Stanford, Calif.
Jones, Bill F., Stanford University, Stanford, Calif.
Mermerci, M., Stanford University, Stanford, Calif.

Ohio Valley Section

Member:
Blackburn, Harry C., Sylvania Electric Products, Inc., Cleveland, Ohio.

Associate Members:
Cobright, Donald, Graybar Electric Co., Inc., Cincinnati, Ohio.
Gambs, Arthur J., Jr., Graybar Electric Co., Inc., Cincinnati, Ohio.
Kristof, Joachim A., Cincinnati Gas & Electric Co., Cincinnati, Ohio.

Student Members:
Armentrout, Everett C., Jr., University of Cincinnati, Cincinnati, Ohio.
Jenkins, R. A., Jr., University of Cincinnati, Cincinnati, Ohio.
Johnson, Donn A., University of Cincinnati, Cincinnati, Ohio.
Painter, Lyle C., University of Cincinnati, Cincinnati, Ohio.
Schaefer, Charles J., University of Cincinnati, Cincinnati, Ohio.
Scherpenberg, Theo A., University of Cincinnati, Cincinnati, Ohio.
Schumacher, Raymond K., University of Cincinnati, Cincinnati, Ohio.
Siebentritt, Carl R., Jr., University of Cincinnati, Cincinnati, Ohio.
Stoms, Richard K., University of Cincinnati, Cincinnati, Ohio.
Weckstein, Norbert L., University of Cincinnati, Cincinnati, Ohio.

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Pickrell, W. E., Stubbs Electric Co., Portland, Ore.
Williams, Ralph E., General Electric Co., Lamp Dept., Portland, Ore.
Williams, W. R., S and M Lamp Co., Portland, Ore.

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Associate Members:
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Deardorf, H. D., Auburn & Associates, Inc., Pittsburgh, Pa.
Hanlon, Thomas P., Hanlon Electric Co., Pittsburgh, Pa.
Moskowitz, Lester R., Westinghouse Electric Supply Co., Pittsburgh, Pa.
Myers, Stuart J., Solar Electric Corp., Warren, Pa.
Pugsley, William H., West Penn Power Co., Pittsburgh, Pa.
Scheib, Arthur W., West Penn Power Co., Charleroi, Pa.
Walter, William E., Fort Pitt Electric Construction Co., Pittsburgh, Pa.

Puget Sound Section

Associate Members:
Flynn, J. F., Puget Sound Power & Light Co., Seattle, Wash.
Watlock, Eldon A., Puget Sound Power & Light Co., Bremerton, Wash.

Rochester Chapter

Associate Members:
Erskine, D., Erskine-Healy, Inc., Rochester, N. Y.
Jutton, Colin G., Rowe Electric Co., Rochester, N. Y.
Vincent, Donald H., General Electric Co., Lamp Dept., Rochester, N. Y.

St. Louis Section

Associate Member:
Keely, Robert J., Jr., Champion Lamp Works, Lynn, Mass.

Southern California Section

Associate Members:
Cooper, V. S., II, General Electric Supply Corp., Los Angeles, Calif.
Freund, Karl, Photo Research Corp., Hollywood, Calif.
Mundy, W. A., Appleton Electric Co., Los Angeles, Calif.
Poor, Fred W., Ralph E. Phillips, City Hall, Los Angeles, Calif.
Pratt, Horace, Cross Lighting Co., Los Angeles, Calif.
Taylor, Bert Raymond, W. P. Fuller & Co., Los Angeles, Calif.

South Texas Chapter

Associate Members:
Kirk, John B., Nunn Electric Supply Corp., Houston, Texas.
Peabody, George A., Peabody Brothers, Houston, Texas.

Schnorbus, W. B., S. B. Schnorbus Electric Co., Houston, Texas.
Roberts, R. A., William B. Terry Organizations, Inc., Houston, Texas.

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Associate Members:

Dodge, James W., Jr., Dodge Electric Supply & Service Co., Tulsa, Okla.
Whitlow, E. J., McClure Electric Co., Dallas, Texas.

TORONTO SECTION

Associate Members:

Currie, G. R., Hydro Electric Power Commission of Ontario, London, Ont., Canada.
McGowan, Leslie R., Canadian General Electric Co., Ltd., Toronto, Ont., Canada.
Stewart, H. R., Allanson Armature Mfg. Co., Ltd., Toronto, Ont., Canada.

TWIN CITY SECTION

Member:

Johnson, L. E., Northern States Power Co., Minneapolis, Minn.

Associate Members:

Baugh, Donald P., Montana Dakota Utilities Co., Bismarck, N. Dak.
Finn, Michael C., General Electric Co., Minneapolis, Minn.
Gombold, W. E., Gombold Electric Co., St. Paul, Minn.
Kufus, Floyd W., General Electric Supply Corp., Minneapolis, Minn.
Johnson, Herman G., Northern States Power Co., Minneapolis, Minn.
Little, Robert D., Balch Sales Co., Minneapolis, Minn.
Myers, W. E., Branham, Marek & Duepner, Inc., Minneapolis, Minn.
Stephens, E. J., Electric Repair & Construction Co., Minneapolis, Minn.
Weidt, Roland A., Alvin L. Weidt & Associates, Minneapolis, Minn.
Welshons, Eugene S., General Electric Supply Corp., St. Paul, Minn.

UTAH CHAPTER

Associate Members:

Jones, Ben F., Sr., Young Electric Sign Corp., Salt Lake City, Utah.
Patrick, John A., Crouse Hinds Co., Salt Lake City, Utah.
Schilperoort, John L. A., Style Electric Co., Salt Lake City, Utah.

WESTERN NEW YORK SECTION

Associate Members:

Dewes, P. Paul, W. A. Case & Son Mfg. Co., Buffalo, N. Y.
Feigel, Charles L., Acme Electric Corp., Cuba, N. Y.

ABOUT PEOPLE

Friends of **Carl A. Atherton**, Honorary Secretary of I.C.I., and a valued member of I.E.S., will be sorry to hear of an accident which almost cost him the sight of one eye. A block of wood, flying from his ax at his New Hampshire farm, pierced his eyeball, necessitating several operations in the effort to save his sight. Mr. Atherton has now returned for a few hours each day to his duties with the International Westinghouse Co., and is continuing his work for the I.C.I.

A. H. Nicoll, president of the Graybar Electric Co., was elected president of the New York Rotary Club at its annual meeting held recently in New York City. He will take office May 5, succeeding Harry D. Schmedes.

Mr. Nicoll, vice-president of the club, has been a member since 1939 and a member of the board of directors for four years.

The appointment of **Dr. Elmer C. Larsen** as chief engineer for the Tungsten and Chemical Division of Sylvania Electric Products Inc. was announced recently by John B. Merrill, division manager. Dr. Larsen will assume direction of the engineering and scientific program for improved production and process control of tungsten and chemical products now being manufactured in increasing volume and variety. Dr. Larsen was formerly assistant director of research for the J. T. Baker Chemical Co. and was associated with the Bell Telephone Laboratories from 1939 to 1945.

G. Gordon Saffer of Omaha, Nebraska, has been appointed to represent Silvray Lighting, Inc., in Missouri, Kansas, Nebraska and Colorado. According to an announcement by H. G. Clum, Sales Manager, this appointment brings the number of field sales representatives to 20, giving complete coverage to the United States. Other recent appointments include **G. H. Arnold** to the Atlanta territory and **Frank M. Moos** to the Florida territory.

Robert L. Zahour has rejoined the Westinghouse Lamp Division, Bloomfield, N. J., and will handle special lamp applications, according to Ralph R. Brady, manager of commercial engineering. In 1923, Mr. Zahour enrolled in the Westinghouse Lamp Company's student engineers' course, and upon graduation became an illuminating engineer in the lighting department where he conducted lighting schools, gave lecture-demonstrations, and supervised research for new lamp applications. In 1935, he left Westinghouse to head lighting and rural electrification promotion for the Connecticut Light & Power Co. in Hartford. In 1930, he received his Master's degree at Case. Mr. Zahour is a registered professional engineer in Connecticut, New Jersey and New York; a member of the New York Section of the Illuminating Engineering Society; a charter member of the Connecticut Section, I.E.S., and a member of the National Society of Professional Engineers.

John Lucian Savage, internationally famous civil engineer, has been designated 1949 winner of the Washington Award, awarded annually by a joint committee of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Society of Mining and Metallurgical Engineers, and the Western Society of Engineers. The award was made at a dinner on April 20 at the Furniture Club of America.

James Lang, Electrical Engineer of the firm Scott, Whitnah, Lang & Associates, has been elected to serve as Director of the Board of the Minnesota Federation of Engineering Societies, representing the Twin City Section of the Illuminating Engineering Society. **A. B. Hallaway** was selected as his alternative.

OBITUARY

Dr. Harvey C. Rentschler passed away at his home in East Orange, N. J., on March 23, following a three-month illness. One of America's outstanding physicists, Dr. Rentschler served for 30 years as director of Westinghouse lamp and electronic tube research at the Lamp Division in Bloomfield, N. J., retiring in July, 1947.

Dr. Rentschler was more recently known for his early work with uranium; work which ultimately led to the development of the atomic bomb.

He patented more than 100 inventions and was the author of many scientific papers. Among his many achievements was the development of the Sterilamp, done jointly with Dr. R. F. James.

Following his retirement from Westinghouse, Dr. Rentscheler became a visiting professor at Princeton University and had taught at the University of Missouri before joining Westinghouse in 1917.

The Society has received with regret a report on the death of **L. E. Fenlon**, Iowa Section, who was killed in an automobile accident on March 19. Mr. Fenlon, a long-time employee of the Iowa Power and Light Co., and a Charter member of the Iowa Section, was killed instantly when his car went out of control on a curve near Des Moines. Mr. Fenlon was instrumental in the formation of the old Nebraska-Iowa Chapter, and throughout the years had been an active and enthusiastic member of I.E.S.

At a meeting of the Puget Sound Section, K. E. Hollingsworth, chairman of the Section, presented a memorial resolution honoring the late **George M. Boyd**, former chairman of the Washington State Chapter. This was in recognition of Mr. Boyd's loyal efforts in developing the science of illuminating engineering to its present high standing. Mr. Boyd died in Seattle on November 13, 1948.

Mr. Boyd was affectionately known and respected by many. He took the lead in the development and promotion of educational programs sponsored by the Society and his most recent accomplishment was the securing of recognition of illuminating engineering as a profession when he appeared before the Washington State Board of Registration for Professional Engineers.

The Section voted that his memorial be sent to National Headquarters of I.E.S., and a copy of it be presented to Mrs. Boyd.

The recent death of **Richard E. Staples**, an active member of the Oregon Section for a number of years, has been reported to headquarters. Mr. Staples was an active participant in all I.E.S. local activities. Particularly energetic in membership work, he was responsible in no small degree for the Oregon Section's top place in the Pacific Northwest Region member rosters.

Mr. Staples was Dealer Cooperation Supervisor with the Portland General Electric Co. Starting his career with the company at Nela Park, Cleveland, Ohio, he was admired for his professional approach in illumination design.

Delayed news of the death last New Year of **Herbert Mayo**, San Marino, California, has recently been received. Mr. Mayo, well known on the west coast for his work in illumination, particularly as an illuminating engineer with the Benjamin Electric Mfg. Co., was an active Member of I.E.S. since 1920. He served nationally on a number of the Society's committees, and was elected for two terms (1938-1940) as Chairman of the Southern California Section.

BOOKS AND PAMPHLETS

Fatigue and Impairment in Man, by Howard Bartley and Eloise Chute (McGraw-Hill, 1947) is a comprehensive analysis of current thinking on the subject of fatigue. However, the book is highly technical and would be of interest only to physiologists, psychologists, and lighting engineers concerned with the relationship between light and vision. Only two of the twenty chapters are at all related to vision.

Throughout the book the authors emphasize the difference between impairment and fatigue. "Impairment is seen as referring to condition of tissue, which is directly discovered only by physiological and biochemical analyses, whereas fatigue is seen as an expression of the organization of the whole organism, which can be described only in personalistic terms. They state that work output is not a valid measure of either fatigue or impairment.

Chapter IX—"Conventional Visual-Fatigue Studies" is an excellent summary of sensory, ergographic, symptomatic, ease of seeing, and conflict methods of studying visual fatigue. One section of Chapter XVI—"Personal Factors in the Work Situation" deals with "work that puts heavy demands upon vision and in which visual deficiencies become crucial." Visual Performance and Fatigue (Chapter XVII) relates to vision as it participates in personal conflict and *contributes* to fatigue. This chapter is divided into the following major sections: Gross Organism-Environment Relations that Lead to Frustration; Geometry, Image Formation, Visual Perception, and Oculomotor Activity; The Motor Factors of Vision.

Price of the book is $5.50 per copy.

ASA Booklet on Electrical Instruments. A more useful presentation of requirements for the individual sizes of panel and switchboard instruments is offered in the new American Standard for Electrical Indicated Instruments, C39.1-1949. The standard was prepared by a committee of the national associations concerned with manufacture, use and technical development of electrical instruments, under the procedure of the American Standards Association. It consolidated for peace-time use the work done with great success during the war, which is credited with having raised the quality of instruments obtainable in the open market. Most of the general material contained in the war standard has been continued for peacetime use but it has been made more useful by rearranging it to give the detailed requirements for each size and kind of instrument on individual sheets. This saves time for those using the standard by giving all the information they may need in one place.

One of the important contributions in the standard is the section on definitions which covers many new definitions not included before. The problem of instrument accuracy where nonlinear scales are used is solved in the standard by a statement fixing the allowable limit of error for these sections of the scale which are cramped or condensed. In addition to definitions and the detailed requirements for each type of instrument, the text of the standard includes general requirements for temperature, effect of overload, shock, vibration, humidity and a dielectric test.

The new standard is Part I, covering only panel and switchboard instruments. Since other problems made the preparation of a standard for portable instruments a long-range project, they will be covered in Part II, to be completed later. Copies may be obtained from the American Standards Association, 70 East 45th St., New York 17, N. Y.

Current Articles on Lighting

The following list presents titles and source of publication of current articles on lighting and allied subjects which have appeared in recent issues of nationally known magazines having a wide circulation.

The Economics of Fluorescent Lighting, by Richard G. Slauer, *Electrical Engineering*, April, 1949, p. 330

Snack Bar Lighting, *Electrical Review*, March 4, 1949, p. 362

Fits Light to the Task, *Electrified Industry*, April, 1949, p. 48

Night Sky Brightness Measurements in Latitudes below 45°, by E. O.

(*Continued on page* 10A)

SUSTAINING MEMBERS

Acme Electric Corp.
Cuba, N. Y. *J. A. Comstock*

Admiral Lamp Manufacturing Corp.
2430 So. Ashland Ave., Chicago, Ill. *F. Schwartz*

Advance Transformer Co.
1122 W. Catalpa Ave., Chicago 40, Ill. *Hirsch Epstein*

Alabama Power Co.
Birmingham, Ala. *George L. Morris*

All Bright Electric Products Co.
3917-25 N. Kedzie Ave., Chicago 18, Ill. *Max Klein*

Amalgamated Electric Corp., Ltd.
384 Pape Ave., Toronto, Ont., Canada *D. W. Patterson*

American Concrete Corp.
4727 North Lamon Ave., Chicago 30, Ill. *J. W. Lewis*

American Fluorescent Corp.
5407 Broadway, Chicago, Ill. *William Rusnak*

American Sterilizer Co.
Erie, Pa. *Horace Wm. Alexander*

Appleton Electric Co.
1701-1729 Wellington Ave., Chicago 13, Ill. *Nils A. Tornblom*

Arkansas Power & Light Co.
Simmons National Bldg., Pine Bluff, Ark. *Max Sudduth*

Art Lamp Corp.
1750 W. Fulton St., Chicago 12, Ill. *B. H. Martin*

The Art Metal Co.
1814 E. 40th St., Cleveland 3, Ohio *George E. Glatthar*

Artistic Lamp Manufacturing Co., Inc.
395 Fourth Ave., New York 16, N. Y. *Myron Perlmutter*

Bausch & Lomb Optical Co.
Rochester 2, N. Y. *David L. Williams*

Benjamin Electric Mfg. Co.
Des Plaines, Ill. *John H. Waterbury*

Blue Ridge Glass Corp.
Kingsport, Tenn. *J. H. Lewis*

Board of Water and Electric Light Commissioners
116 W. Ottawa St., P.O. Box 570, Lansing 3, Mich. *John D. Malnight*

Boston Edison Co.
39 Boylston St., Boston 12, Mass. *R. B. Brown, Jr.*

Bright Light Reflector Co., Inc.
Fairfield & State, Bridgeport 5, Conn. *C. E. Scholl*

British Columbia Electric Rwy. Co., Ltd.
570 Dunsmuir St., Vancouver, B. C., Canada *H. N. Walters*

Brockton Edison Co.
36 Main St., Brockton 67, Mass. *W. A. Forbush*

Buffalo Niagara Elec. Corp.
Buffalo 3, N. Y. *Jack F. Parsons*

Edward F. Caldwell & Co., Inc.
101 Park Ave., New York 17, N. Y. *E. T. Caldwell*

California Electric Power Co.
P.O. Box 512, Riverside, Calif. *W. S. Fleming*

Cal-Lite, Inc.
12600 S. Yukon Ave., Hawthorne, Calif. *N. L. Ureles*

Calpa Products Co.
4116 Chester Ave., Philadelphia 4, Pa. *Paul C. Calisi*

Cambridge Electric Light Co.
46 Blackstone St., Cambridge 39, Mass. *Reginald H. Bowman*

Canadian General Elec. Co., Ltd.
212 King St., Toronto, Ont. *R. M. Love*

Canadian Laco Lamps, Ltd.
745 Guy St., Montreal, Que. *J. Thomas*

Canadian Line Materials, Ltd.
Postal Station H, Toronto 13, Ont., Canada *L. E. Messinger*

Central Hudson Gas and Elec. Corp.
50 Market St., Poughkeepsie, N. Y. *H. E. Dexter*

Central Illinois Light Co.
316 Jefferson Ave. S., Peoria 2, Ill. *R. K. Dallas*

Central Illinois Public Service Co.
607 E. Adams St., Springfield, Ill. *B. L. Palm*

Central Maine Power Co.
9 Green St., Augusta, Maine *Roland W. Hess*

Central New York Power Corp.
300 Erie Boulevard W., Syracuse, N. Y. *L. D. McCormac*

Central Power & Light Co.
P.O. Box 2121, Corpus Christi, Texas *James M. Williams*

Champion Lamp Works Div. of Consolidated Electric Lamp Co.
600 Broad St., Lynn, Mass. *Ellery H. Raddin*

Chicago Miniature Lamp Works
1500 North Ogden, Chicago, Ill. *Edward M. Pollock*

Cincinnati Gas & Electric Co.
Fourth & Main Sts., Cincinnati 1, Ohio *J. R. Hartman*

Circlite Corp.
118 So. Clinton St., Chicago, Ill. *George Gomberg*

City of Burbank, California Public Service Department
174 W. Magnolia Boulevard, Burbank, Calif. *J. H. McCambridge*

City of Glendale Public Service Dept.
119 N. Glendale Ave., Glendale 6, Calif. *P. Diederich*

City of Riverside Electric Light Dept.
3854 Mulberry St., Riverside, Calif. *L. W. Grayson*

City of Seattle, Dept. of Lighting — Puget Sound
1015 Third Ave., Seattle 4, Wash. *P. C. Spowart*

Colonial Electric Products Co., Inc.
1-115 Market St., E. Paterson, N. J. *Wallace M. Woodworth*

Colonial Premier Co.
466 W. Superior St., Chicago 10, Ill. *Richard Weis*

Commercial Light Co.
841 W. Washington Blvd., Chicago, Ill. *Michael R. Fine*

Commonwealth Edison Co.
72 W. Adams St., Chicago 90, Ill. *Ralph G. Raymond*

The Connecticut Light & Power Co.
250 Freight St., Waterbury 91, Conn.

Consolidated Edison Co. of N. Y., Inc.
4 Irving Place, New York 3, N. Y. *Clarence Law*

Consolidated Gas, Elec. Light & Power Co. of Baltimore
100 W. Lexington St., Baltimore 1, Md. *R. H. Tillman*

Consumers Power Co.
212 Michigan Ave. W., Jackson, Mich. *D. E. Karn*

Consumers Public Power Co.
1452-25th Ave., Columbus, Nebraska *W. H. Sinke*

Corning Glass Works
Corning, N. Y. *A. S. Tylor*

Coyne Electrical School, Inc.
500 So. Paulina St., Chicago 7, Ill. *John Hanan*

Crescent Electric Supply Co.
765 Iowa St., Dubuque, Iowa *Titus B. Schmid*

Crouse-Hinds Co.
Syracuse 1, N. Y. *A. H. Clarke*

Crouse Hinds Co. of Canada, Ltd.
7 Labatt Ave., Toronto, Ont. *F. R. Jeffery*

Curtis Lighting, Inc.
6135 W. 65th St., Clearing Station, Chicago 38, Ill. *Darwin Curtis*

Curtis Lighting of Canada, Ltd.
195 Wickateed Ave., Leaside, Toronto 12, Ont. *H. L. Wright*

Cutler Light Manufacturing Co.
2026-28 N. 22d St., Philadelphia 21, Pa. *Robert T. Cutler*

Dallas Power & Light Co.
1506 Commerce St., Dallas 1, Texas *W. G. Moore*

Day-Brite Lighting, Inc.
5401 Bulwer St., St. Louis 7, Mo. *D. J. Biller*

The Dayton Power & Light Co.
25 No. Main St., Dayton, Ohio *H. S. Nonneman*

Dazor Manufacturing Corp.
4483 Duncan Ave., St. Louis 10, Mo. *P. L. Read*

Delaware Power & Light Co.
600 Market St., Wilmington 99, Del. *W. A. F. Pyle*

Dept. of Water & Power, City of Los Angeles, Bur. of Power & Light
Box 3669 Terminal Annex, 207 So. Broadway, Los Angeles 54, Calif. *C. P. Garman*

Detroit Edison Co.
2000 Second Ave., Detroit 26, Mich. *L. E. Tayler*

Detroit Steel Products Co.
2250 E. Grand Blvd., Detroit 11, Mich. *W. Clifton Randall*

Dobkin Electrical Supply Co.
329 W. Madison St., Chicago, Ill. *Jerry Dobkin*

E. I. duPont de Nemours & Co., Inc. (Fabrics & Finishes Div.)
Wilmington 98, Del. *S. W. Quisenberry*

Duquesne Light Co.
435 Sixth Ave., Pittsburgh 19, Pa. *G. W. Ousler*

Duro Test Corp.
2321 Hudson Blvd., North Bergen, N. J. *James L. Cox*

Eastern Fixture Co., Inc.
170 Vernon St., Boston 20, Mass. *Louis Gilman*

East Side Metal Spinning & Stamping Corp.
1 W. 34th St., New York 1, N. Y. *M. A. Kremer*

Ebasco Services, Inc.
2 Rector St., New York 6, N. Y. *W. E. Parrott*

Efengee Electrical Supply Co.
671 W. Washington St., Chicago 6, Ill. *Louis Coleman*

Electrical Information Publications, Inc.
20 E. Mifflin, P.O. Box 232, Madison, Wis. *W. N. Dudley*

Electrical Testing Laboratories, Inc.
79th St. & East End Ave., New York City 21, N. Y. *Preston S. Millar*

Elec. Service Mfg. Co.
17th & Cambria Sts., Philadelphia 32, Pa. *E. A. Leinroth*

Electric Supply Corp.
701 W. Jackson Blvd., Chicago 6, Ill. *L. B. Mangione*

(*Note*: Names of Official Representatives appear in Italics)

Electro Manufacturing Corp.
2000 W. Fulton St., Chicago 12, Ill.
L. K. Schoenbrod

Electrolier Mfg. Company, Ltd.
5849 Boyer St., Montreal, Que., Canada.
John Issenman

Ender Manufacturing Corp.
260 West St., New York 13, N. Y.
Jules Levenstein

Englewood Electrical Supply Co.
5801-03 So. Halsted St., Chicago, Ill.
Ray O'Leary

Famous Fluorescent Light Co.
762 N. Ogden Ave., Chicago 22, Ill.
Jack R. Stone

Federal Electric Company, Inc.
8700 S. State St., Chicago, Ill.
John H. Goehst

Fitchburg Gas & Electric Light Co.
537 Main St., Fitchburg, Mass. *A. G. Neal*

Fluorescent Equipment & Mfg. Co.
2570 Superior Ave., Cleveland 14, Ohio
Leonard S. Freeman

Fluorescent Maintenance Co., Inc.
1480 S. Robertson Blvd., Los Angeles 35, Calif. *Leonard K. Black*

Fluores-O-Lite Co.
Evans Terminal, No. Broad St., Hillside, N. J.
Meyer H. Silverman

The Fostoria Pressed Steel Corp.
Fostoria, Ohio *E. L. Bates*

M. A. Framburg & Co.
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Stanley A. Framburg

The France Mfg. Co.
10325 Berea Rd., Cleveland 2, Ohio
J. H. Mayne

The Frankelite Co.
1425 Rockwell Ave., Cleveland 14, Ohio
Dave Frankel

Franklin Design Service, Division of Safeway Stores, Inc.
4th & Jackson Sts., P.O. Box 660, Oakland 4, Calif. *H. J. Dutton*

The Frink Corporation
27-01 Bridge Plaza North, Long Island City, N. Y. *Theo. J. Brussel, Jr.*

Gallagher-O'Brien Electric Co., Inc.
712 N. State St., Chicago 10, Ill.
Frank A. Gallagher

Garden City Plating & Mfg. Co.
1750 No. Ashland Ave., Chicago 22, Ill.
G. G. Harney

General Electric Co., Apparatus Dept.
Schenectady 5, N. Y. *A. F. Dickerson*

General Electric Co., Lamp Dept.
Nela Park, Cleveland 12, Ohio
Willard C. Brown

General Electric Supply Corp.
1260 Boston Ave., Bridgeport, Conn.
W. W. Booth

General Lighting Products Co.
16 Delancy St., Newark 5, N. J.
Nathan H. Eglowstein

General Outdoor Advertising Co., Inc.
515 So. Loomis St., Chicago, Ill. *R. E. Nevius*

The Georgia Power Co.
Electric Building, Atlanta 1, Ga.
Charles A. Collier

Gibson Manufacturing Co.
1919 Piedmont Circle, N. E., Atlanta, Ga.
R. R. Gibson

Gill Glass & Fixture Co.
Amber & Tioga Sts., Philadelphia 34, Pa.
C. A. Gill

Gillinder Brothers, Inc.
Erie & Liberty Sts., Port Jervis, N. Y.
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Gleason-Tiebout Glass Co.
99 Commercial St., Brooklyn 22, N. Y.
Charles W. Gleason

Globe Lighting Products Co., Inc.
397 Seventh Ave., Brooklyn, N. Y.
Isidor Rosenblatt

Golde Manufacturing Co.
1214 West Madison, Chicago 7, Ill.
E. W. Goldberg

Grand Rapids Store Equip. Co.
1340 Monroe Ave., N. W., Grand Rapids 2, Mich. *Kenneth C. Welch*

Graybar Electric Co., Inc.
420 Lexington Ave., New York 17, N. Y.
Raymond C. Kinney

Gulf States Utilities Co.
Box 2951, Beaumont, Texas *Clarence Barron*

The Edwin F. Guth Co.
2615 Washington Ave., St. Louis 3, Mo.
Fred E. Guth

Hartford Electric Light Co.
266 Pearl St., Hartford 3, Conn.
Victor Ouellette

Hawkins Electric Co.
1447 Washington Blvd., Chicago 7, Ill.
R. R. Hill

Hendrickson-Heffernan Co., Inc.
45-17 Pearson St., Long Island City 1, N. Y.
Joseph T. Manucia

Holdenline Co.
2301 Scranton Rd., Cleveland 13, Ohio
H. E. Ingraham

Holophane Company, Inc.
342 Madison Ave., New York 17, N. Y.
H. L. Logan

Houston Lighting & Power Co.
P.O. Box 1700, Houston 1, Texas
H. O. Clarke

Hydro-Electric Power Comm. of Ont.
620 University Ave., Toronto, Ontario.
R. L. Hearn

Hyland Electrical Supply Co.
700 West Jackson Blvd., Chicago, Ill.
Chas. H. Weicensaang

Illinois Power Co.
134 East Main St., (L Box 511 B), Decatur 70, Ill. *Allen Van Wyck*

Illuminating Engineering Co.
2347 E. Nine Mile Road, Hazel Park, Mich.
Bert C. Pretzer

Iowa-Illinois Gas & Electric Co.
United Light Bldg., Davenport, Iowa
John M. Hollingsworth

Iowa Public Service Co.
400 Commercial St., Waterloo, Iowa
C. R. Wagoner

Jeannette Shade & Novelty Co.
N. Fourth St., Jeannette, Pa. *H. N. Crock*

Jefferson Electric Co.
Bellwood, Ill. *L. Maurer*

Jersey Central Power & Light Co.
501 Grand Ave., Asbury Park, N. J.
Thomas R. Dobson

Joleco Corporation
2513 Baldwin St., St. Louis, Mo.
George Ledbetter

Jones Metal Products Co.
West Lafayette, Ohio *H. Boyer*

Joslyn Mfg. & Supply Co.
3700 So. Morgan St., Chicago 9, Ill.
J. H. Fahey

Kahn Manufacturing Co., Inc.
2051 N. 19th St., Milwaukee, Wis.
Charles F. Kahn

Kansas City Power & Light Co.
P.O. Box 679, Kansas City 10, Mo.
John M. Arthur, Jr.

Kansas Gas & Electric Co.
P.O. Box 204, Wichita, Kans. *H. W. Hobson*

The Kawneer Co.
North Front St., Niles, Mich.
Richard M. Spray

The Kayline Company
2480 E. 22nd St., Cleveland 15, Ohio
M. A. Eskins

Kelso-Burnett Electric Co.
223 W. Jackson Blvd., Chicago 6, Ill.
Sigmund A. Hollinger

Keystone Electric Manufacturing Co.
2228-36 E. Tioga St., Philadelphia 34, Pa.
Leonard M. Siegel

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3435 E. Jefferson Ave., Detroit 7, Mich.
Ivan Kirlin

Kopp Glass, Inc.
Swissvale, Pa. *F. C. Ashe*

Kubec Electric Co.
630 W. Jackson Blvd., Chicago 6, Ill.
Fred A. Girten

The La Salle Lighting Products, Inc.
145 Seneca St., Buffalo 3, N. Y.
Nelson R. Zicherman

Leader Electric Manufacturing Corp.
3500 N. Kedzie St., Chicago 18, Ill.
Walter Glass

The Leeds & Northrup Co.
4901 Stenton Ave., Philadelphia 44, Pa.
I. M. Stein

The Leland Electric Co.
1501 Webster St., Dayton, Ohio
Harold A. Cline

Libbey Owens Ford Glass Co., Plaskon Division
2112-24 Sylvan Ave., Toledo, Ohio
Dr. M. H. Bigelow

Light Control Company
3217 Casitas Ave., Los Angeles 26, Calif.
Stanley E. Lindahl

Lighting & Lamps
114 East 32nd St., New York 16, N. Y.
James Krieger

Lighting Incorporated
1834 So. Figueroa St., Los Angeles, Calif.
Harry Marsh

Lighting Products, Inc.
2259 W. Park Ave., Highland Park, Ill.
D. E. Dunne

Lightolier Co.
11 East 36th St., New York 16, N. Y.
H. Stollnitz

Line Material Co.
800 North 8th St., Milwaukee 1, Wis.
M. C. Harsh

Litecontrol Corp.
36 Pleasant St., Watertown 72, Mass.
Paul H. Lamson

Louisiana Power & Light Co.
142 Delaronde St., Station "A," New Orleans, La. *C. L. Osterberger*

Luminator, Inc.
120 N. Peoria St., Chicago 7, Ill.
Albert L. Arenberg

T. R. Lyda Manufacturers Rep.
4922 Washington Blvd., Indianapolis, Ind.
T. R. Lyda

Lynn Gas & Electric Co.
90 Exchange St., Lynn, Mass. *James A. Cook*

Macbeth Corp.
227 West 17th St., New York, N. Y.
Norman Macbeth

Malden Electric Co.
157 Pleasant St., Malden, Mass.
Donald S. Bennett

Markel Electric Products, Inc.
145 E. Seneca St., Buffalo 3, N. Y.
D. L. Ripley

Markstone Manufacturing Co.
1917 N. Springfield Ave., Chicago 47, Ill.
M. J. Marks

La Cie Martineau Electrique Ltee.
24 rue du Roi, Quebec, Canada
Henri Martineau

Metalcraft Products Company
306-08 Cherry St., Philadelphia 6, Pa.
Alex Abel

Metal Window Institute
Cheltenham, Pa. *George Hingston*

Metropolitan Edison Co.
412 Washington St., Reading, Pa.
E. J. Ingram

Metropolitan Electrical Supply Co.
20 N. Jefferson St., Chicago 6, Ill.
H. J. Privat

Midwest Chandelier Co.
15th & Gentry Sts., No. Kansas City 16, Mo.
Sidney Lefkovitz

The Miller Co.
Meriden, Conn. *G. W. Beals*

Mississippi Glass Co.
220 Fifth Ave., New York City 1, N. Y.
E. H. Hobbie

Mississippi Power Co.
Gulfport, Miss. *R. M. Shearer*

Mississippi Power & Light Co.
Lampton Building, Jackson 113, Miss.
Henry B. Sargent

Mitchell Manufacturing Co.
2525 Clybourn Ave., Chicago 14, Ill.
Bernard Mitchell

Mobilite Inc.
440 Mercer St., Jersey City, N. J.
Sidney Solmor

Modern Light Co.
1512 Pine St., St. Louis 3, Mo.
Karl L. Rundberg

Modern Light & Equip. Co.
3812 S. Wabash Ave., Chicago, Ill.
M. L. Ofgenberg

Moe-Bridges Corp.
1415 Illinois Ave., Sheboygan, Wis.
J. G. Rainey

Montana-Dakota Utilities Co.
831 Second Ave. So., Minneapolis 2, Minn.
W. L. Hayes

Municipal Light and Power Dept.
City of Pasadena, California, 302 City Hall, Pasadena 1, Calif. *E. L. Bettannier*

Mutual Sunset Lamp Mfg. Co., Inc.
540 Empire State Bldg., New York 1, N. Y.
Morris Thau

The Narragansett Electric Co.
49 Westminster St., Providence 1, R. I.
C. R. Broadhead

National Chemical & Manufacturing Co. Luminall Paint Div.
3617 So. May St., Chicago 9, Ill.
John Marshall Zic

National Lighting Products
4221 W. Harrison St., Chicago 24, Ill.
D. J. Epp

Nebraska Power Co.
720 Electric Bldg., Omaha 2, Neb.
G. A. Walker

Nelson-Tombacher Co.
81 Prospect St., Brooklyn, N. Y.
M. J. Tombacher

New Bedford Gas & Edison Light Co.
693 Purchase St., New Bedford, Mass
W. S. Fenstermacher

New Orleans Public Service, Inc.
317 Baronne St., New Orleans, La.
S. L. Drumm

New York Power & Light Corp.
Albany 1, N. Y. *Coburn D. Hollister*

Northern Electric Co. Ltd.
1620 Notre Dame St., West, Montreal, Quebec.
F. P. Labey

Northern Indiana Public Service Co. Gary Div.
500 Broadway, Gary, Ind. *J. C. Sackman*

Northern States Power Co.
Minneapolis 2, Minn. *Carl T. Bremicker*

Ohio Edison Co. (Akron Div.)
Akron 8, Ohio *E. F. Hartenstein*

The Ohio Power Co.
301-315 Cleveland Ave., S. W., Canton 2, Ohio
C. B. Morin

The Ohio Public Service Co.
P.O. Box 6058, Cleveland 1, Ohio.
C. L. Dunn

Oklahoma Gas & Electric Co.
Box 1498, Oklahoma City 1, Okla.
E. W. Gray

Omaha Public Power District
720 Electric Bldg., Omaha 2, Nebraska
E. E. Schwalm

Overbagh & Ayres Mfg. Co.
411 S. Clinton St., Chicago 77, Ill.
Alfred A. Overbagh

Pacific Gas & Electric Co.
245 Market St., San Francisco 5, Calif.
O. R. Doerr

Pacific Power & Light Co.
522 Public Service Bldg., Portland 4, Oregon
C. A. Root

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Pennsylvania Electric Co.
535 Vine St., Johnstown, Pa.
Frank R. Knowles

Pennsylvania Power Co.
19 E. Washington St., New Castle, Pa.
P. G. Dingledy

Pennsylvania Power & Light Co.
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J. M. Stedman

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Dr. Frank W. Preston

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John H. Pierce

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R. B. Tucker

Pittsburgh Reflector Co.
403-411 Oliver Bldg., Pittsburgh 22, Pa.
H. C. Zinsmeister

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Walter Lown

Portland General Electric Co.
Electric Bldg., Portland 5, Ore. *T. W. Fitch*

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S. S. Bradford

Public Service Co. of Colo.
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G. O. Stewart

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H. P. J. Steinmetz

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T. E. McDowell

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Dwight E. Worrell

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Floyd Fernau

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Gordon K. Cameron

Rochester Gas & Electric Corp.
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Nyack, N. Y. *D. S. Schaab*

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222 W. Washington Sq., Philadelphia 5, Pa.
F. W. Tetzlaff

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Ben Ruby

Ruby-Philite Corp.
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Lubin & Smalley Florists, Pittsburgh, Pennsylvania. Only six MITCHELL Model No. 3020B Slimline fixtures required to achieve 85 foot candles in this florist shop, as well as brilliant show window illumination.

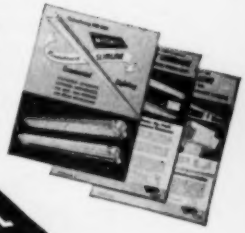
Right across the country, businesses of *every kind* are turning to MITCHELL "Slimline" to get the "selling" light they need. It's uncanny how one installation sells another—in whole communities the commercial lighting swing is to MITCHELL "Slimline".

Progressive businessmen prefer this handsome, smooth, powerful lighting that creates a traffic-building sales-inviting atmosphere. They like the way MITCHELL "Slimline" puts appeal into merchandise, makes it more desirable and easier to sell—the way it produces *measurable* increases in sales and profits.

This user acceptance builds volume business for the wholesaler. MITCHELL "Slimline" installations are easy, smooth jobs for the contractor—time-saving profitable business. And utility men can recommend this superior lighting with confidence.

Whether it's automobiles or lilacs—MITCHELL "Slimline" lights *and sells* them all!

Write for complete descriptive literature covering MITCHELL Slimline fixtures. Ask for Bulletin No. 322 describing 4-Lamp units; Bulletin No. 339 describing 2-Lamp units; Bulletin No. 334 describing spotlight units, for use with Slimline fixtures.



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First Choice in Lighting

Mitchell Manufacturing Company

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The Oriental Gardens indicate the natural beauty which surrounds the French Lick Springs Hotel. In the background is Pluto Spring, most famous of the three mineral springs at French Lick.

French Lick has two challenging golf courses, plus a tricky pitch-and-putt course of nine holes. Other sports facilities include swimming in an outdoor and two indoor pools, horseback riding, tennis, archery, croquet, trap-shooting and bowling.

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- A rare opportunity to combine business with relaxation and pleasure.
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- Unusual entertainment, with planned relaxation on all four nights of the Conference. Details are, of course, a secret.
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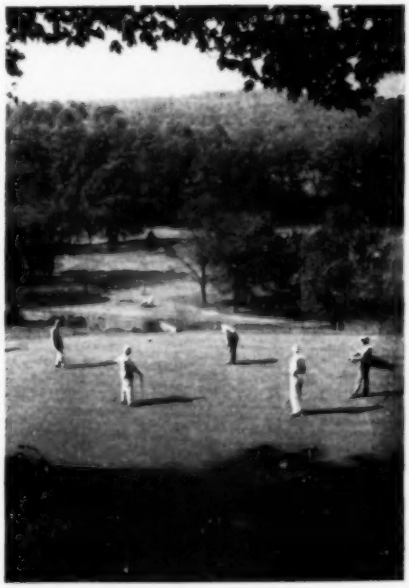

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It's French Lick in 1949
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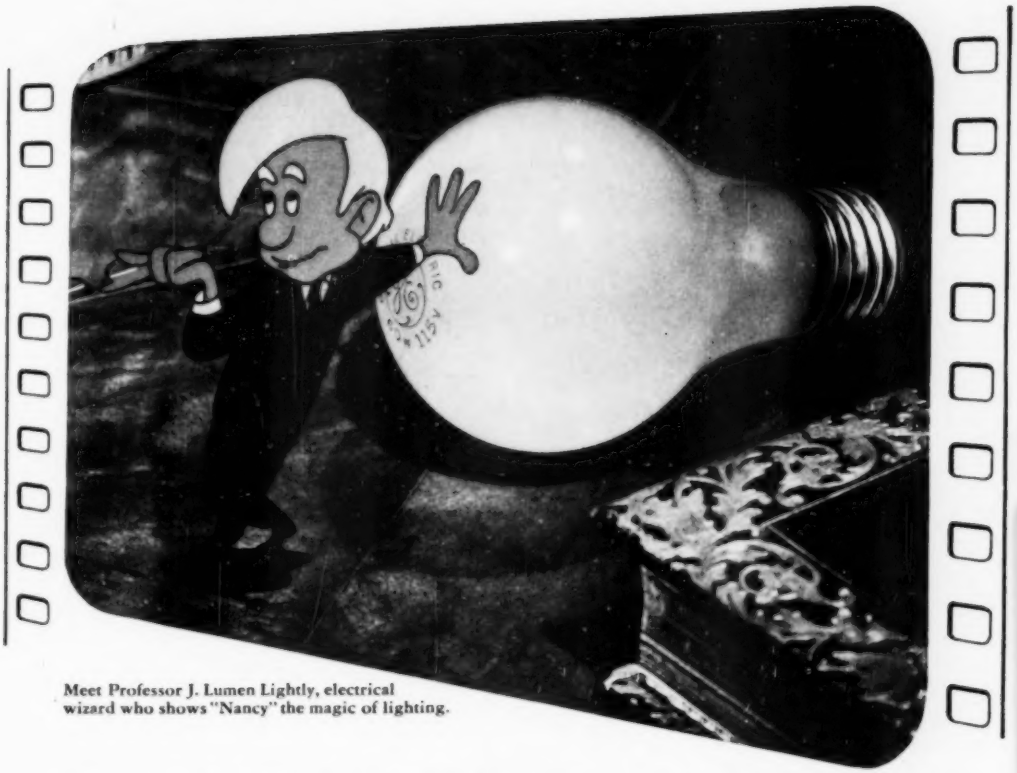

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THE LIGHT IN YOUR LIFE

"Nancy" and the Professor go in for air travel while he points out how lighting works for everyone.

Shows people the importance of lighting

"The Light in Your Life" is one of the most interesting and entertaining educational films ever made. It's science, sell, and fun wrapped in the neatest picture-package in years!

Enjoyable to everyone . . . from kids to captains of industry. And we're showing it all over the country to expand the market for better lighting.

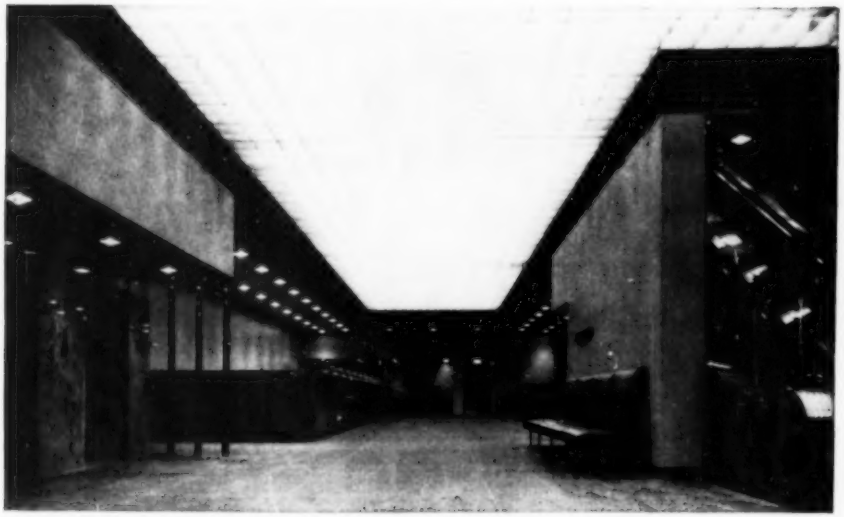
General Electric will be glad to show you "The Light in Your Life" soon—just call your nearest G-E Lamp Department office right away!

ANOTHER SALES AID

GENERAL ELECTRIC

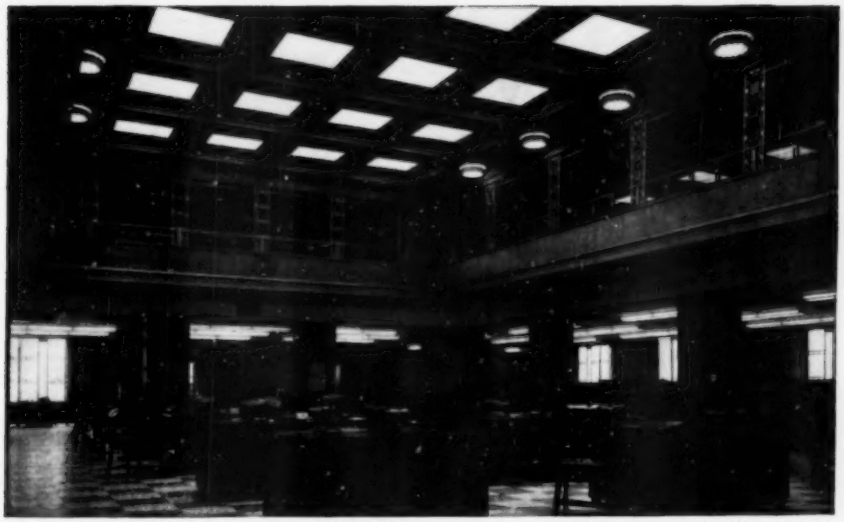
Three reasons why Cleveland banks on Frink for lighting

Today, the city of Cleveland is favored with three of the finest new lighting installations in the country. While vastly different in design and technique, they have one thing in common... they all were *manufactured by FRINK*, one of America's leading specialists in planned lighting.



CENTRAL NATIONAL BANK OF CLEVELAND . . . this striking Frink installation is an outstanding example of modern louverall ceiling lighting. To achieve efficient, even distribution of diffused light, the louvers are made of high-reflectivity satin anodized aluminum. The louver sections are specially constructed for easy accessibility to lamps. *Architects: Conrad, Hays, Simpson & Ruth.*

PLANNED LIGHTING AT ITS FINEST...



SOCIETY FOR SAVINGS IN THE CITY OF CLEVELAND . . . a fine example of an installation combining Frink *custom-built* and *standard* lighting equipment. Hinged double louvered units are recessed into each ceiling bay to create a skylight effect and provide efficient overall lighting. Standard *L-I-N-O-L-I-T-E* Series 22 fixtures are ceiling mounted under the mezzanine. *Architects: Garfield, Harris, Robinson and Schafer.*

THE NATIONAL CITY BANK OF CLEVELAND . . . this officers' area is effectively lighted by an attractive and highly efficient arrangement of *standard* Frink fixtures. To achieve a high level of evenly distributed light, *L-I-N-O-L-I-T-E* Series 12 units, *only three inches deep*, are ceiling mounted in continuous rows, with lamps shielded by hinged, removable glass-paneled doors. *Architects: Dalton & Dalton & Associates.*

The 1949 line of standard *L-I-N-O-L-I-T-E* fluorescent fixtures includes a wide variety of designs suitable for every commercial lighting purpose. In addition, Frink specializes in the design and manufacture of *custom-built* lighting expertly designed, engineered and manufactured to individual requirements. Write today for your copy of the new Frink Catalog, and packet of sample PLAN-O-LITE layouts, photographs and engineering data on typical Frink installations to The Frink Corporation, 27-05 Bridge Plaza North, Long Island City, N. Y.

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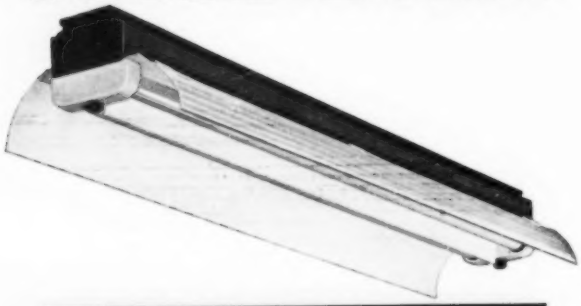
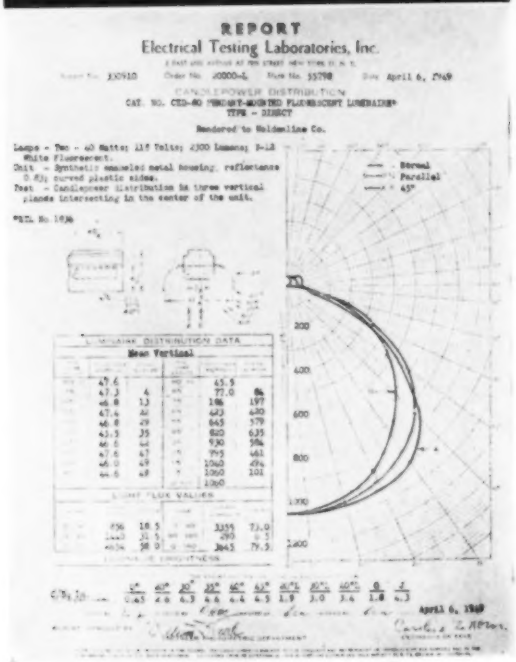
Quality.... is not accidental!



CED-80


REPORT
Electrical Testing Laboratories, Inc.
CANDLEPOWER DISTRIBUTION
CAT. NO. CED-80 "SURFACE-MOUNTED FLUORESCENT LUMINAIRE"
TYPE - DIRECT
Rendered to Holdenline Co.
Lamps - Two - 40 Watts; 115 Volts; 2300 Lumens; T-12 White Fluorescent.
Unit - Synthetic enameled metal housing, reflectance 0.85; curved plastic sides.
Test - Candlepower distribution in three vertical planes intersecting in the center of the unit.
Normal
Parallel
45°
Mean Vertical
April 6, 1949

HOLDENLINE Co.

Pioneers In Fluorescent

2287 Scranton Rd. • Cleveland 13, Ohio

HOLDENLINE—T.M. REG. U. S. PAT. OFF. 1937

(*Continued from page 318*)

Hulburt, *Journal of the Optical Society of America*, March, 1949, p. 211

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Precision-Formed Filaments on New G.E. Projection Lamps, *International Projectionist*, March, 1949, p. 23

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(*Continued on page 15A*)

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a new high in lighting

New flexibility of application
of the 96 in. slimline fluorescent lamp.
New simplified installation,
operation and maintenance.
Write for miller slimline catalog 2G.

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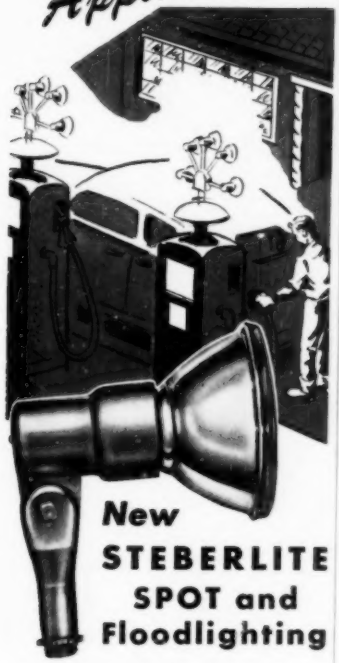

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Here's an inexpensive lamp holder for spot and floodlighting service stations, business areas, playgrounds, parking lots and numerous other applications. Steberlites for 150 to 500 watt projector and reflector type lamps are complete units and do not require any other small parts. Steberlites save labor and wiring costs. They are compact, weather-proof and completely wired, ready for quick assembly and installation, indoors or out. Steberlites can be used singly, in pairs, or clusters of 3, 4 and 5. Only a few basic units are necessary to serve most requirements. Write for new Bulletin 120.

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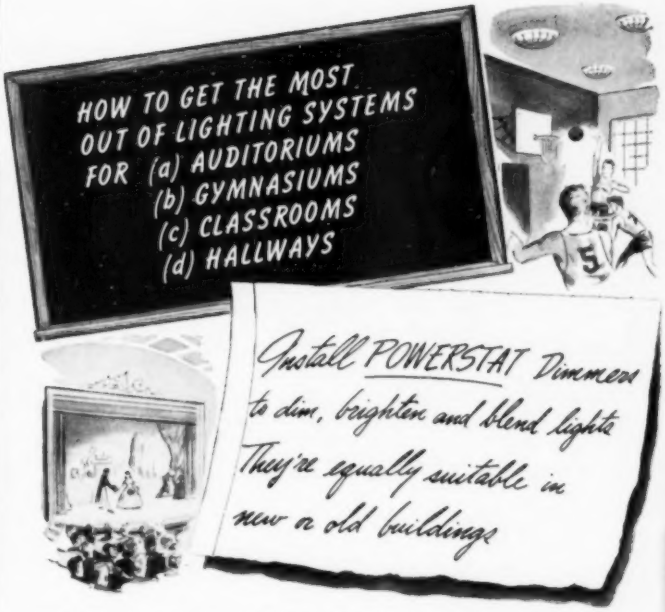
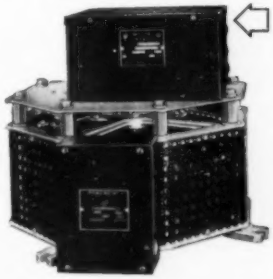
Broadview (Maywood P. O.), Illinois



You'll get more out of your lighting systems — more out of your buildings — with POWERSTAT light dimming equipment installed in your school lighting circuits. Auditoriums equipped with POWERSTAT Dimmers find more evening use for plays, social and civic functions. Gymnasiums are made more suitable for dances, parties and bazaars when lights can be dimmed, brightened or blended to suit the occasion. Extra activity means more frequent rentals — increased income from units otherwise unprofitable.

Classroom lighting, when controlled by a POWERSTAT Dimmer, can be set to the most effective levels to accurately offset poor natural lighting conditions. Hallway lighting can be increased to full brilliancy for class changes — dimmed to economical levels when traffic loads are negligible.



POWERSTAT light dimming equipment is simple to install — easy to operate. By merely pushing a button the desired light level is achieved. Push-button stations can be placed at any convenient location.

We'll be glad to send you complete information on how POWERSTATS *can be used in your plans for school lighting — write us today.*

WRITE 5059 DEMERS AVENUE, BRISTOL, CONNECTICUT

THE SUPERIOR ELECTRIC CO.

BRISTOL, CONNECTICUT

Powerstat Variable Transformers • Voltbox A C Power Supply • Stabiline Voltage Regulators.

THIS BALLAST IMPROVES

LIGHTING PERFORMANCE

Blinking lamps, slow lighting lamps, end-blackened lamps, stroboscopic light patterns, humming fixtures, these are indications that should lead you to replace those defective ballasts with Acme Electric fluorescent lamp ballasts. Acme Electric ballasts provide the exact starting and operating current and wattage output required to properly operate the lamps. Better engineered, better construction, better performance. Write for Bulletin FL 167.

ACME ELECTRIC CORPORATION

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Acme Electric

Now Is The Time—

TO LIGHT UP THAT PLAY AREA.

CAT. NO. 8088 B

750-1500 Watts
18" Diam.

This **MULTI** open type floodlight is engineered to give maximum flexibility of light direction with simple adjustment methods.

It's durable, too — heavy steel finished in porcelain enamel.

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ACHIEVE DECORATIVE BEAUTY
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ORIGINAL SOLID CORRUGATED GLASS

Corrugated Glass is widely used in partitions to provide individual offices of taste and quiet dignity. The effectiveness of vertical lines, accentuated by the sparkling highlights of the corrugations accomplishes the overall result for which modern decorators strive.

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1612 MARKET STREET PHILA. 3, PA.

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Transport Lighting with Fluorescent Lamps, by H. R. Ruff, J. N. Hull, and R. V. Mills, *Transactions of the Illuminating Engineering Society* (London), Volume XIV, No. 3, 1949, p. 57

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Just the Light She Needs, by Elizabeth Beveridge, *Woman's Home Companion*, March, 1949, p. 72.

ATTENTION!

Manufacturers' representatives are wanted to sell efficient FLOLITE COLD CATHODE FLUORESCENT LAMPS and FLOLITE REFLECTOR UNITS to custom fixture manufacturers. Protected territory. Write us today for full particulars.

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The only **Slimline** fixture with downlight reflectors for maximum benefit from the new lamps. Greatest light-producer—sleek appearance. Easy to handle. One man can install it. Simplified wiring. Immediate delivery.

Versatile! For 2 or 4 lamps—open, with eggcrate louvres, or glass diffusers—mounted flush or suspended, in units or rows. For 200, 300 and 425 m.a. lamp intensities.

To make sure of *all* the advantages of **Slimline** lighting, specify the **GUTH Slimline Trucolite***—the time-tested, high-level light producer! Send today for Bulletin 852-I with full details.

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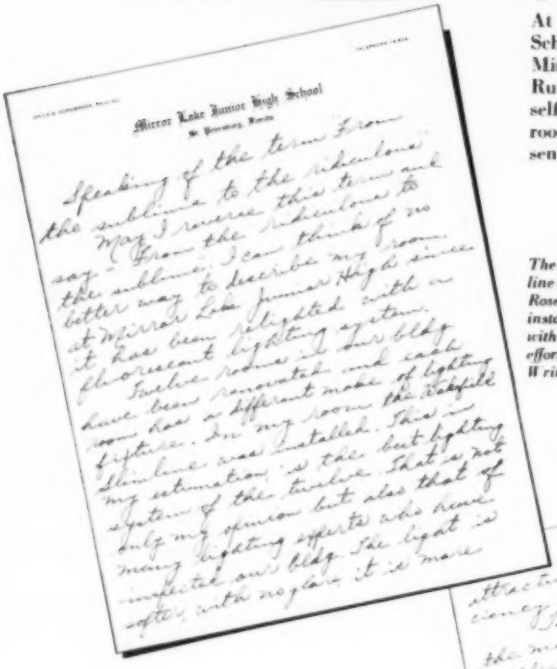
THE EDWIN F. GUTH COMPANY / ST. LOUIS 3, MISSOURI

*Ⓡ—U. S. Patent Nos. 122586, 2331774

821

Leader in Lighting since 1902

The Children Brought Their Parents To See This Newly Lighted Classroom


Mirror Lake Junior High School
St. Petersburg, Florida

Speaking of the term from the sublime to the ridiculous, may I reverse this term and say — From the ridiculous to the sublime. I can think of no better way to describe my room at Mirror Lake Junior High since it has been lighted with fluorescent lighting system. Twelve rooms have been renovated and each room has a different make of lighting fixtures. In my room the Wakefield Slimline was installed. This is my estimation is the best lighting system of the twelve. That is not only my opinion but also that of many lighting experts who have inspected our bldg. The light is soft, with no glare, it is more attractive and the lighting efficiency is of a high degree. Since we also the opinion of the majority of my students, the children are more alert, happier and their general morale greatly improved. This is evidenced by the fact that we many times brought there parents in to see it.

If you have never sat in the gloom trying to read and had someone suddenly turn on a light you can have no conception of and like the present lighting.

Since we had no choice in the lights to be installed in our rooms I am glad mine are Wakefield Slimline. I like mine so much better, I consider myself very fortunate in getting them.

Wakefield Slimline.

Ruth D. Downer
Social Studies
Instructor in Head

(Wakefield)

At the Southeastern School Lighting Institute and School Lighting Exhibit held April 19, 20 and 21 at Mirror Lake Junior High School, St. Petersburg, Fla., Ruth Downer, social studies teacher, expressed herself so enthusiastically about the new lighting in her room, that we asked her if she'd mind putting her sentiments into a letter. She did, and here's her letter:

★ ★ ★

The installation consisted of 3 rows of Wakefield Stars with Slimline lamps. The Wakefield Star has proved itself outstanding in the Rosedale School experiment at Austin, Texas, and in many other installations. If you are concerned over providing your students with a visual environment in which seeing becomes relatively effortless, we have much valuable information and data for you. Write The F. W. Wakefield Brass Company, Vermilion, Ohio.

Wakefield Over-ALL Lighting

A BASIC CLASSROOM TOOL

THE GRENADIER II

THE COMMODORE

THE STAR

G-45-30-2-P

What does this FLEUR-O-LIER INDEX SYSTEM NUMBER MEAN?

In a specification, it denotes the exact kind of lighting performance desired. "G" stands for General Diffuse lighting distribution; "45" for 45° side shielding; "30" for 30° end shielding; "2" for a brightness in shielded zone of not more than 2½ footcandles per square inch; "P" means Pendent mounting.

For a fixture, those symbols mean that Electrical Testing Laboratories, Inc., after photometric tests, find it has those performance characteristics.

Thus, it is now possible for the specifier to express simply and precisely the lighting performance he wants. And the buyer can now buy fixtures and know in advance how they will perform when installed. For, in addition to the Index System rating, complete photometric data, together with coefficients of utilization are supplied for each Fleur-O-Lier fixture,

And the Fleur-O-lier label certifies that the fixture is "right" mechanically and electrically.

Fleur-O-Lier Gives *Complete* Information —

All the data needed to make an intelligent choice of fixtures is provided by Fleur-O-Lier. You get—

1. An Index System Rating
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You're *sure* when you insist on Fleur-O-Lier.

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Fleur-O-Lier is not the name of an individual manufacturer, but of a group of fixtures made by leading manufacturers. Participation in the Fleur-O-Lier program is open to any manufacturer who complies with Fleur-O-Lier requirements.

tests like this

To assure uniform brilliancy, a Westinghouse worker in the Fairmont, W. Va. plant gives "Easter egg" test to 100-watt fluorescent lamp. The brilliant radiation of this industrial lamp is measured through a tiny hole in sphere's side by an electric eye.

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YOU CAN BE SURE...IF IT'S

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